Engineers' Ch

Showing the Developm

of the STEAM BOILE

STEAM ENGIN

and ELECTRIC GENER

BY

JOSEPH G. BRANCH

THE

ENGINEERS' DESCRIPTIVE

With Full Explanatory '

By JOSEPH G. erald BRANCH, B. S., M. E.

Former Chief of the Department of Inspection Boilers and Elevators and Member of the Bc
of the City of St. Louis. Member of the American Society of Mechanical Engineers
and Light from Municipal and Other Waste, Conversations on El
Stationary Engineering, etc.

Showing the Development of the

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A Book Written Expressly for Schools and Engir

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TABLE OF CONTENTS

THE STEAM BOILER

THE STEAM ENGINE

THE ELECTRIC GENERATOR

THE STEAM BOILER

NEWCOMEN "BALLOON" OR "HAYSTACK" BOILER

Designed by Thomas Newcomen About the Year 1715.

lesigned the first **PRACTICAL** steam boiler?

: the first forms of steam boilers was a **SPHERICAL** boiler designed by Newcomen in the few years later he designed the **FIRST PRACTICAL** steam boiler. It was a vertical er, called from its shape the **"BALLOON"** or **"HAYSTACK"** boiler. This boiler is shown 1. It was of wrought iron with a hemispherical top and with an arched bottom, as shown ion. The steam space necessary in every boiler is designated by the numeral 1, the eath the shell by 2, the flue conveying the hot gases around the shell by 3, the chimney team outlet from the boiler to the engine by 5. From this it can be seen that this the first **ESSENTIALS** of all properly constructed steam boilers, viz.:—a **VESSEL** to er; a **FURNACE** underneath it and a **FLUE** to bring the hot gases of combustion in is vessel; sufficient **SPACE** above the water in the vessel to hold the steam; and lastly, convey away these gases and supply the necessary air for combustion.

what engine was this boiler used?

EWCOMEN ENGINE with which this boiler was used only required steam slightly above the atmosphere (14.7 lbs), hence Newcomen had no difficulty in having his boilers made ng to withstand such pressure.

at materials were Newcomen's earlier boilers constructed?

wcomen's early boilers the lower part of the boiler was made of **COPPER** and the upper

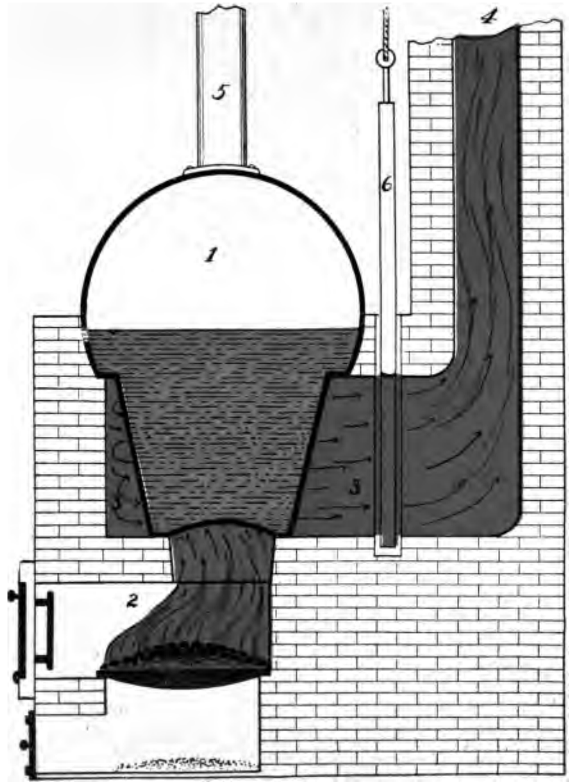

Illustration 1.

ıll the earlier boilers were used for supplying steam to lift water, usually from mines. ; little pressure was required to operate Newcomen's engine, but with the **SAVERY** receded Newcomen's engine, the height to which water could be raised was limited by f the steam. As boiler-making was almost unknown at that time, but few of the er came into use, it being impossible to construct a boiler strong enough to withstand essure required for this character of engine.

ımen engine, it being an **ATMOSPHERIC ENGINE**, the pressure of the steam had no height to which the water could be raised, only about 15 lbs. pressure being necessary, ble to make a boiler to withstand this low pressure and at the same time do satis-

en boiler and engine were in general use for a number of years, giving very satisfac- e character of work required.

Ṭhe principal defect in this boiler was the lack of heating surface exposed to the fire ich was partially due to the short travel of the gases.

meant by the **HEATING SURFACE** of a boiler?

HEATING SURFACE of a boiler we mean only that portion of the shell which is ıal contact with the fire and heated gases. It is evident the greater the heating ːr the amount of heat that can be imparted to the water, and consequently the greater ıporation of same into steam.

the chief consideration in the **CONSTRUCTION** of all steam boilers?

boiler is used to make steam for the work to be performed. This is the **CHIEF CON-** 1 all boilers are constructed with this object in view. The boiler that can evaporate

the most water into steam with the greatest **ECONOMY,** is the most successful boiler. Fo hundred years it has been the constant endeavor of engineers the world over to produce a per that is, a boiler in which there will be no loss of heat, but its entire utilization in the w performed.

THE WATT "WAGON" BOILER

Designed by James Watt in the Year 1785

Q. Who improved upon Newcomen's boiler?

A. In order to improve upon the boiler above described, **WATT** designed a horizontal boi a greater heating surface. From its resemblance to a wagon top, this boiler was called the boiler. This boiler is shown in **Ill. 2.** The top was hemispherical, and the bottom curved The numeral 1 designates the steam space, the furnace underneath the shell is designated chimney by 3, the safety valve by 4, the steam outlet to the engine by 5, the damper by automatic pressure gauge and damper regulator by 7. The products of combustion passed from underneath the boiler to the rear, then through the left-hand flue to the front, and from there through the right-hand flue, passing the front of the boiler to do so, finally escaping up the From the circuit taken by the heated gases first under and then around the shell, this was **"WHEEL DRAFT."**

In the large sizes, the heating surface was further increased by placing a **FLUE** in the boile which the gases returned to the front of the boiler after passing to the rear, as in the smaller s gases, on issuing from the flue at the front, divided and passed to the chimney at the rear of t by flues placed in the brick work on either side. This was called the **"SPLIT DRAFT."**

Q. What improvement was made in the **TRAVEL** of the gases?

A. The travel of the gases was much longer in this boiler than in the "Balloon" boiler. This was reat improvement, as the greater the travel of the gases, the greater is the amount of heat conveyed the water to be evaporated. Should the heated gases have too short a travel between the furnace l the chimney, they will be permitted to escape up the chimney while retaining much of their heat. :h loss of heat means a waste of fuel, and no boiler can be a successful boiler which is so con- ucted as to permit this waste. In any properly constructed boiler and furnace, the heat of the furnace ıbout 2,000 degrees Fahrenheit, while the heated gases rarely escape under ordinary conditions above › degrees Fahrenheit. This means that there has been 1,400 degrees of heat given up during the vel of the gases. With a properly constructed boiler and under proper conditions the temperature the chimney gases can be reduced as low as 400 degrees Fahrenheit, but this is rarely done under or- ary conditions. To reduce the temperature of the gases below this point would effect the draft.

ATTACHMENTS.—Watt used with his boiler a water column in the feed pipe which served as ressure gauge. The rise and fall of this column not only designated the amount of steam pressure the boiler, but also controlled the damper which regulated the draft. The feed water was regulated a float, which, while not now in use, gave engineers their present idea of automatic boiler feed ulators.

DEFECTS.—The chief defect in this "Wagon" boiler was its **WEAKNESS,** owing to its shape and absence of all stays and braces. For low-pressure purposes, not exceeding 15 pounds per square h, it was a practical and useful boiler, but for high-pressure work it was entirely unsuitable.

Watt was much opposed to high steam-pressures, and would not use an internal flue in his boilers

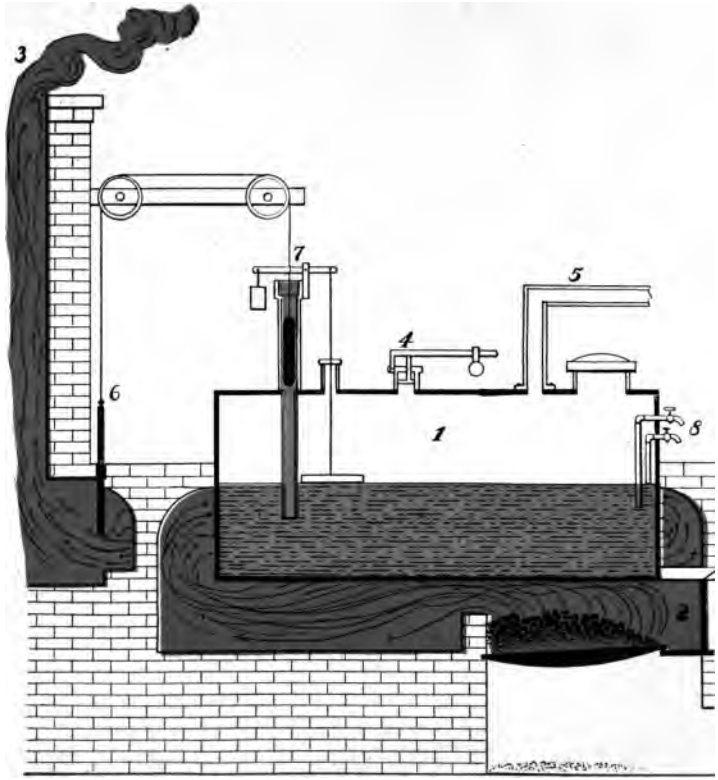

Illustration 2.

›out the year 1796, after the success of an internal flue boiler had been fully demonstrated by
l Trevithick.

THE CYLINDRICAL "EGG END" BOILER

What was the next step in the development of the steam boiler?

Watt's "Wagon" boiler was succeeded about the beginning of the present century by the first of
DERN type of boilers. This was the plain "Cylindrical" boiler made of wrought iron, with flat or
ıerical ends, known as the "Egg end" boiler. The egg shape of the ends of this boiler greatly in-
its strength over that of the "Wagon" boiler, the principal defect of which was its **WEAKNESS.**
FECTS.—Owing to the shape of this boiler no staying is required; its form, with the exception
phere, being the strongest to resist rupture. The heating surface is small, unless the boiler is
ery long, which is a decided disadvantage. All the sediment collects in the bottom of the shell
he heat is the greatest, which soon causes the plates to burn, and also prevents, together with
e which soon forms, the proper conduct of the heat to the water. These boilers are necessarily
diameter, being from 30 to 42 inches, and quite long, being from 20 to 50 feet, and are ex-
wasteful of fuel. They can therefore for this reason be used only in places where fuel is abun-
; in mining districts, and around blast furnaces.

is boiler is shown in **Ill. 3.** The numeral 1 is the shell, the ends being set horizontally in brick
The lower part of this cylinder contains the water, the upper part the steam, 2 the furnace out-
cylinder, which consists simply of grate bars set in the brick work at convenient distance below
:om of the shell, 3 the flues on each side of the shell. The fuel is thrown on the bars through the

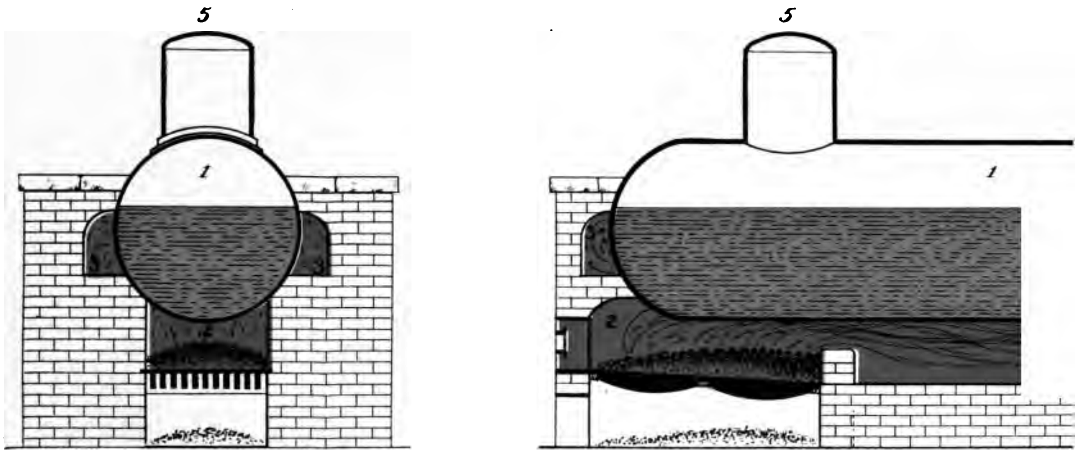

Illustration 3.

loor which is set in the front brick work. The air necessary for combustion enters between the bars from below through the ash pit. The flame and hot gases pass over the bridge wall close : the boiler, thence along the flue to the rear, returning to the front through the flue on the other of the shell and back again on the opposite side to the far end of the boiler, whence they escape le chimney 4. The steam dome from which the dry steam is supplied to the engine is designated while the damper to regulate the draft is designated by 6.

Q. What are the two great **DEFECTS** in this boiler?

A. This boiler is a great improvement upon the earlier types of boilers, but has the two great de- above named, viz.: the lack of proper heating service, and the deposit of solid matter of the water e highly heated portion of the shell forming the bottom of the boiler.

In addition to these two defects, and also owing to the difference in temperature of the gases due to long travel, the expansion and contraction of the metal composing the shell of the boiler is very ual, producing cracks in the metal and rupture of the joints. While the travel of the gases in the r types of boilers was much too short, in this boiler it is **TOO LONG,** owing to the three turns : and around the boiler, which they are forced to take before escaping up the chimney.

As these boilers are frequently made 40 feet long, the gases would be required to travel 120 feet e reaching the far end of the boiler. As their temperature on starting at the forward end of the would be about 2,000 degrees Fahrenheit, after traveling 120 feet in contact with the cooling sur- of the boiler, they would be at times reduced to a temperature barely sufficient to produce a draft e chimney. The effect of this was to highly heat one end of the boiler, leaving the other end cold.

This boiler possesses many of the requirements of the modern boiler, and it should therefore be ughly understood before begining the study of the more modern types.

THE CORNISH BOILER

Designed by Richard Trevithick in the Year 1796

Q. Who improved upon the cylindrical boiler and how?

A. Upon the defects of the above boiler becoming apparent, a Cornish Trevithick, in order to increase the heating surface of same, conceived the idea **SIDE** of an **INTERNAL FLUE** which ran the entire length of the shell. This t the **"CORNISH BOILER," Ill. 4.** It consists of a cylindrical shell with flat er tration. The furnace, however, instead of being outside of the shell, is **ENCLO** or flue having a diameter a little greater than half of that of the boiler shell. heating surface of the entire length and diameter of this second cylinder or flu the grate and bridge wall is evident from the cut. After passing over the brid through this internal cylinder or flue until they reach the rear end of the boile again through the two side flues, and thence back again to the chimney thro numeral 1 in the illustration is the outer cylinder or shell, 2 the internal cylinc side flues, and 4 the bottom flue through which the gases pass finally to the ch let to the engine is in top of the dome 5.

ADVANTAGES.—This type of boiler removed one of the chief objections t by reducing the temperature of the heated gases before they came in contac boiler where the sediment collects. It further **INCREASED** the amount of th boiler by an amount equal to the surface of the internal flue. As the diame had to be made sufficiently large to contain the furnace, it practically prev

iler in small sizes. It was the first type of what is known as the **INTERNALLY FIRED BOILER.**

DEFECTS.—The chief defect in this boiler is the unequal expansion and contraction due to the use the outer and inner cylinder; as the internal flue is the hottest portion of the boiler; and consequently dergoes much greater expansion than the other cylinder. The result is to bulge out the ends of the iler, and then when the boiler cools down, or is out of use, the flue contracts to its regular size, and us has a tendency to work loose from the ends to which it is riveted. Should the ends be too **RIGID** move, a serious strain is thrown on both ends of the flue and the heads of the boiler. Even while in e the flue of this boiler undergoes great changes in temperature, according to the state of the fire. is constant expansion and contraction so weakens the flue that it frequently **COLLAPSES,** resulting great disaster and loss.

Both Richard Trevithick and his son made great improvements in the steam boiler. In 1799 chard Trevithick, junior, built a boiler of wrought iron 24 feet in diameter. A large copper tube irting from the bottom of the boiler immediately over the fire, passed through the boiler and served an internal flue. The outside of this globular boiler was also surrounded by flues. In 1800 Trevi-ck built a cylindrical boiler of wrought iron with **EXTERNAL** furnace and flue, which carried a steam essure of 25 lbs. per sq. inch.

Q. What other great improvement did Trevithick make in the **CONSTRUCTION** of the steam iler?

A. He was the first to use **CAST IRON** for boilers, and in 1856 he built boilers which carried from to 100 lbs. of steam pressure to the square inch.

Trevithick's engines were called **"PUFFERS,"** due to the escape of the exhaust steam from the cyl-ler. Previous to his engine, all engines had been **CONDENSING** engines.

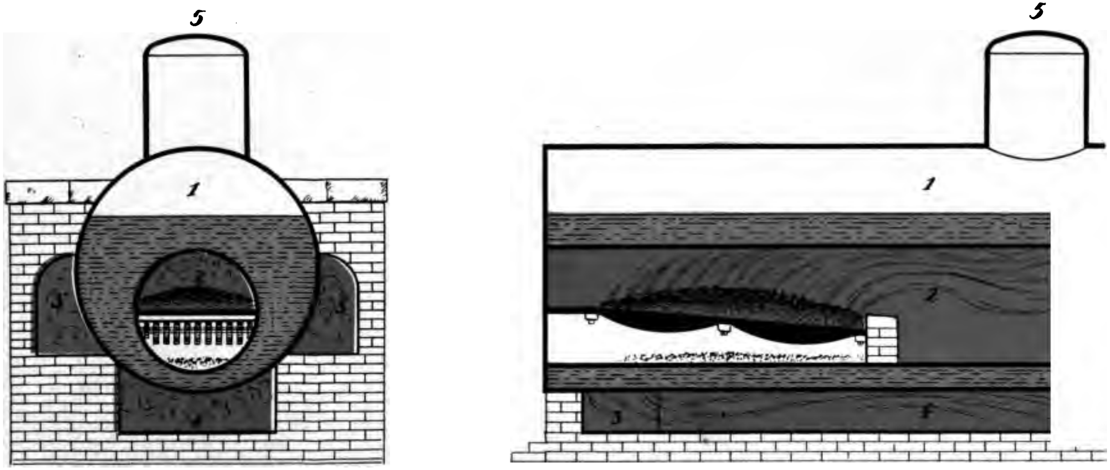

Illustration 4.

'he exhaust steam from his engines he used to heat the **FEED WATER** for his boiler which y reduced the cost of their operation by the saving in fuel.

THE "LANCASHIRE" BOILER

). Who rectified the most serious **DEFECTS** in the Cornish boiler and how?

\. To rectify the most serious defects of the Cornish boiler, the next step in the development of eam boiler was the production of the **LANCASHIRE BOILER,** shown in **Ill. 5.**

n this boiler it will be observed there are **TWO** internal furnaces instead of one as in the "Cornish" . They usually emerge into one internal flue, though sometimes each flue continues to the other f the boiler as a separate flue. These furnaces are supposed to be fired alternately, and the smoke nburned gases from the fresh fuel in one flue is aided in their combustion by the hot air proceeding the other furnace. In this way all violent changes in the temperature are avoided, as well as the of fuel due to escape of the unburned gases. In the illustration showing this boiler, the numeral ne of the internal furnaces, and 12 indicates what are known as the **"GALLOWAY" TUBES.**

). How are these **GALLOWAY TUBES CONNECTED,** and in what way do they add to a boiler?

\. These tubes are connected across the flues as shown in **Ill. 6,** and not only contribute to **NGTHEN** the flues, but they also add greatly to the heating surface, and greatly promote the circula- f the water to be evaporated.

These Galloway tubes were the first steps towards the development of what is known as the **ER TUBE** boiler. A Lancashire boiler fitted with these tubes is known as a **GALLOWAY** boiler.

n order to fully realize what an important step these tubes form in the development of the steam

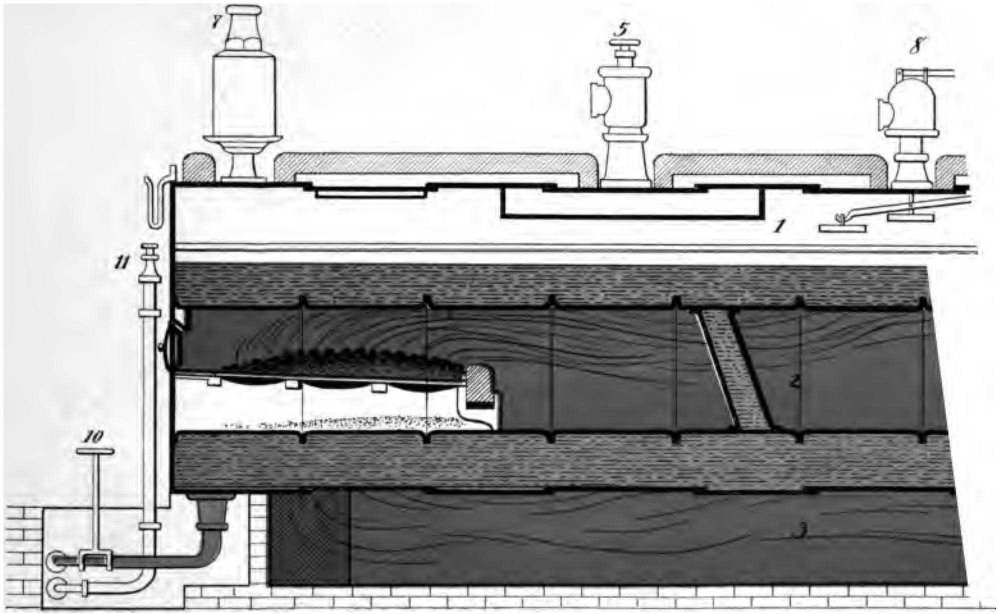

Illustration 5.

fficient to say that there can be no steam evaporated from water in any useful quantities, s no **CIRCULATION** of the water itself. It is the rising of the heated particles of the op, and the descent of the cooler ones to the bottom upon which the formation of steam deherefore absolutely necessary that there be some circulation of the water in all boilers, and of the boiler depends to a great extent upon the proper circulation being afforded. The irculation, the more **RAPID** the evaporation, and, to a large extent the greater the he boiler. The Galloway boiler was the first boiler in which an attempt was made to se- **CIRCULATION,** and while the method pursued was most primitive, it marked a great ad- n engineering.

cashire boiler fitted with these Galloway tubes is shown in **Ill. 5,** together with the numer- tachments, which add both to its safety and economy. The illustration represents a ection of the boiler together with these fittings. There are two safety valves shown on oiler, one being 5, which is of the dead weight type and which will be described hereafter; 8, being a low-water safety valve. This last valve is operated by means of a lever and e attached to a float, which rests on the surface of the water. Upon the water sinking per level, the float also sinks, causing the valve to open, thus allowing steam to escape and m. 4 is the chimney. 9 is the manhole with its cover plate, which manhole admits of interior of the boiler. 13 is the mud hole through which the sediment accumulating along the boiler is removed. 6 is the damper and 7 the steam outlet. On the front of the boiler the pressure gauges, the water gauges, and the furnace door, as well as the feed pipe and pipe. There are also two iron doors by which access may be gained to the two lower for cleaning purposes.

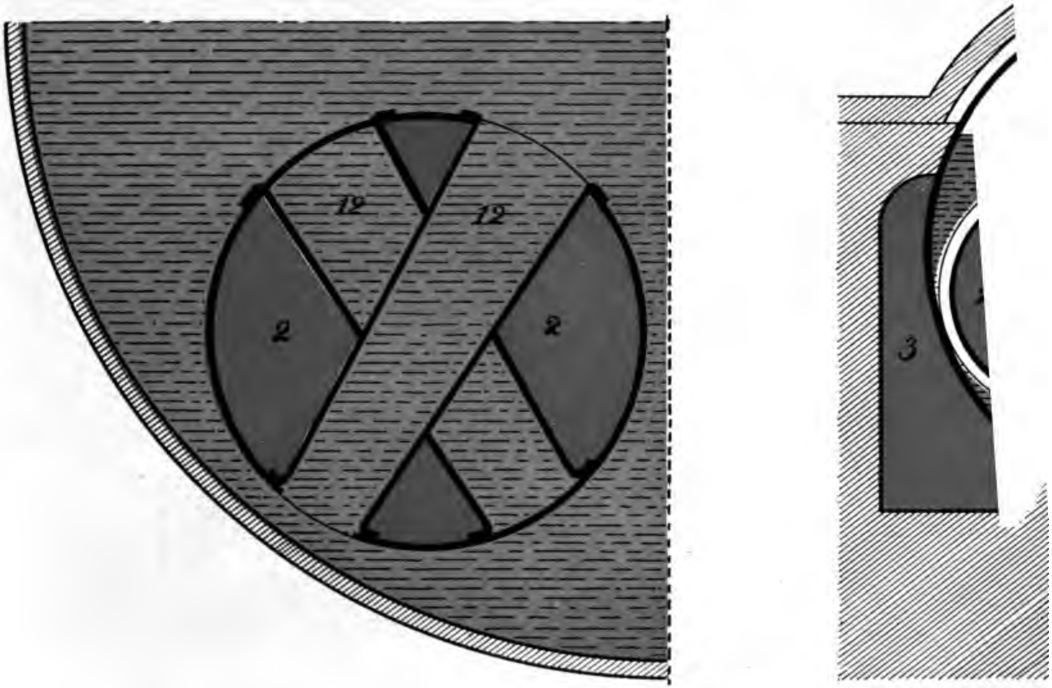

Illustration 6.

AGES.—The Galloway, or Lancashire boiler as it is variously called, is considered a most iler, both in this country and in England. A great many exhaustive tests and experi- een made with this boiler, and its great worth is universally recognized.

S.—The chief defect of this boiler is the difficulty of securing adequate space for two out unduly increasing the diameter of the shell. Where the furnaces are **TOO SMALL,** be complete combustion owing to the cold crown plate of the boiler coming in contact ed furnace, also the narrow space between the fuel and the crown sheet does not permit quantity of **AIR** being supplied above the fuel necessary for perfect combustion.

MODERN TYPES OF BOILERS

ILL. 7 AND ILL. 8

cribe a **MODERN** steam boiler?

development of the **MODERN TYPES** of boilers from the Lancashire or Galloway boiler ort step.

oon found that the placing of an internal flue in the shell not only greatly increased the ce but added to the strength of the boiler, so additional flues were added; and as the e flues were increased it became necessary to **DECREASE** their diameter, until finally the of horizontal tubular boilers were produced.

creasing the diameter of the flues, they soon became too small to be used for furnace pur- e furnace was then placed on the **OUTSIDE** of the shell, making the boiler an **EXTER-** boiler.

S OF BOILERS.—From the placing of the **FURNACE** either **INSIDE** or **OUTSIDE** of the

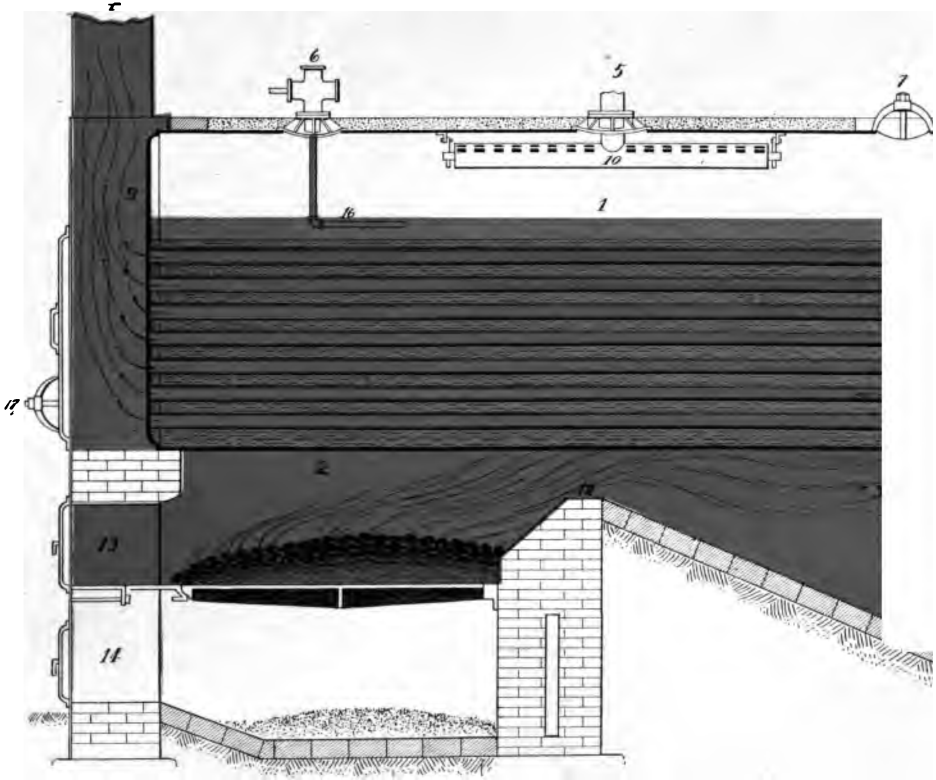

Illustration 7.

l, all steam boilers are divided into two principal classes, viz.: (1) **INTERNALLY** fired boilers, and **EXTERNALLY** fired boilers.

All steam boilers are further divided into two classes according to the **COURSE** taken by the gases r leaving the furnace; one class being composed of **SHELL OR FIRE TUBE BOILERS,** as shown **ll. 7,** in which the hot gases pass **THROUGH** the flues or tubes, thus heating the water which surıds them; while the second class are composed of **WATER TUBE BOILERS**, as shown in **Ill. 8** hich the gases pass **AROUND** the flues or tubes, and in this way heat the water which fills the tubes.

MULTITUBULAR BOILER.—The continual increase of the number of flues, or tubes as they are ed when less than 6 inches in diameter, developed what is known as the **MULTITUBULAR** or **RE-RN TUBULAR BOILER,** in which there are often as many as 130 3-inch tubes, or 84 4-inch tubes.

Q. Describe a modern **SHELL** or **FIRE TUBE** boiler?

A. In **Ill. 7,** is shown a modern **SHELL OR FIRE TUBE** boiler, in which the numeral 1 designates steam space, showing the proper height at which the water should be carried. The furnace 2 is **OUT-E** of the shell, making this an **EXTERNALLY** fired boiler. The **TRAVEL** of the heated gases is wn by 3-3, the chimney by 4, the steam outlet by 5, the feed pipe by 6, the man-hole for cleaning poses by 7, clean-out door by 8, the smoke box by 9, the perforated baffle plate to secure dry steam 10, the blow-off pipe by 11, the bridge wall by 12, the fire door by 13, the ash door by 14, a non-ducting material to prevent radiation of heat by 15, the feed pipe by 16 and a hand-hole by 18.

Q. Describe a modern **WATER TUBE** boiler.

A In **Ill. 8** is shown a modern water tube boiler, in which the numeral 1 designates a horizontal ım and water drum, 2 the furnace, 3-3-3, the travel of the gases, 4-4 two vertical vessels or "water legs" ch form the end connection between the tubes and the combined steam and water drum or "shell"

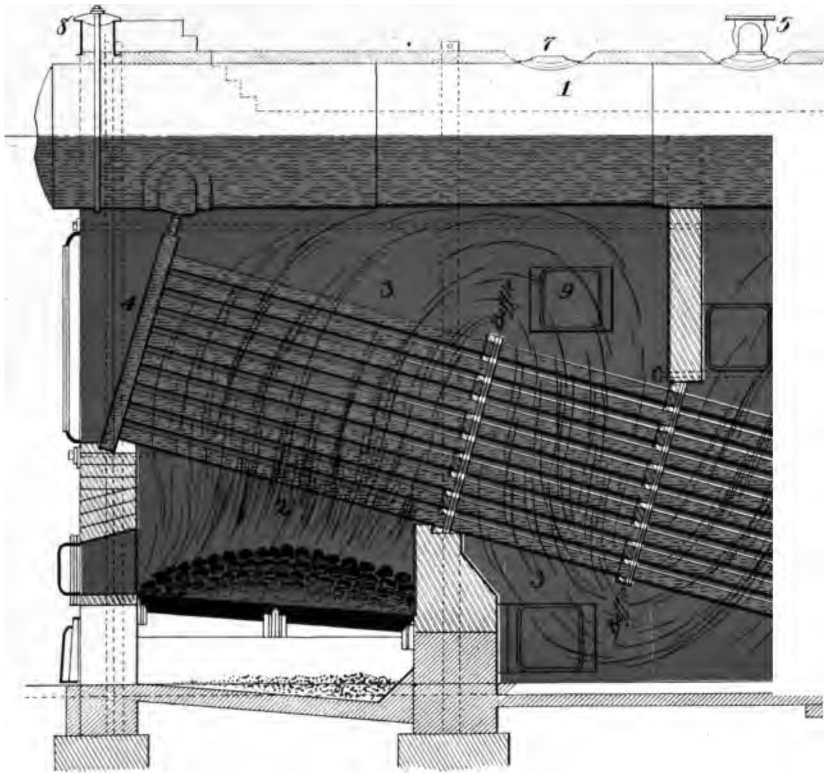

Illustration 8.

above and parallel with them, 5 is the steam outlet to engine, 6 damper opening to stack, 7 is ɔle for cleaning, 8-8 are wrought iron girders resting on iron columns for suspension of the boiler ; it entirely independent of the brick work, 9 is the cleaning out door, and 10 a mud-drum · placed to the rear and the lowest point in the boiler for the purpose of collecting the **SETTLE-** where it can more easily be blown out of the boiler.

ATERIAL.—The steam and mud-drums are usually made of flange iron or steel, of extra thick- ıd double riveted. The tubes are usually lap-welded wrought iron, and the mud-drums are of ɔn, it being the best material to withstand corrosion.

The Steam Engin

THE STEAM ENGINE

What is a **STEAM ENGINE?**

It is an apparatus for converting **HEAT** into mechanical power.

What was the **FIRST** steam engine?

A **STEAM TURBINE.**

Who invented the **FIRST** steam turbine?

Hero of Alexandria about the year 120 B. C.

Describe it?

It was a **REACTION** turbine consisting of a hollow sphere mounted on trunnions through steam was admitted to the interior. The steam escaped through pipes bent **TANGENTIALLY** to ere, as shown in **Ill. 1.** The force of the escaping steam **REACTED** upon the sphere, causing it lve on its trunnions, hence it was called a **REACTION** turbine?

Who invented the next known type of steam turbine?

Branca, in the year 1629.

Describe it?

It was an **IMPULSE** wheel, in which a jet of steam **IMPINGED** upon the flat vanes of a wheel, wn in **Ill. 2.** The dynamic pressure, of **IMPULSE,** of the steam caused the wheel to rotate, hence called an **IMPULSE** turbine.

Who constructed the **FIRST** practical steam engine?

THOMAS SAVERY, in the year 1693.

For what purpose was the **SAVERY** engine used?

For **PUMPING** water out of a mine, as were all of the first constructed engines.

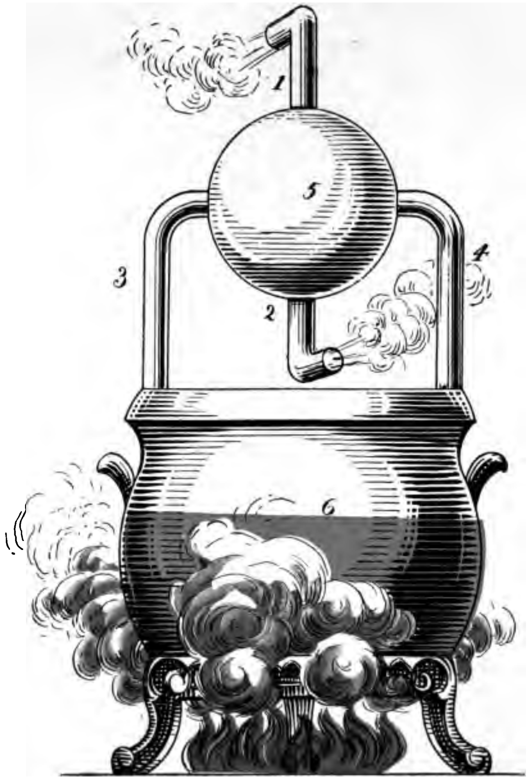

Illustration 1.

Describe the Savery engine?

It consisted simply of **TWO** oval vessels placed side by side and in communication with iler. The lower parts of the vessels were connected together by tubes fitted with suitable :eam from a boiler was admitted to one of the vessels and then condensed by cooling the ' the vessel with water. In this way a **VACUUM** was formed **INSIDE** the vessel, which upon he valve drew up the water from the mine until the vessel was full. The valve was then d steam again admitted, so that upon opening the second valve the water was forced out by ıre of the steam through the discharge pipe, and the vessel again filled with steam ready to :ondensed. In this way the two vessels were worked **ALTERNATELY,** so that while one was d the other was open to the boiler and being emptied. This engine is shown in **Ill. 3.**

How could a **VACUUM** draw up water from a mine?

The atmospheric pressure on the water in the mine was about **FIFTEEN** pounds per square .e the pressure in the vessel containing the vacuum was much less, probably only **FIVE OR NDS** per square inch, hence the water was **FORCED** up into the vessel.

Could not **ALL** the pressure be removed from the inside of the vessel by creating a perfect

Yes, if a **PERFECT VACUUM** could be created in the vessel there would be no pressure in the t it is impossible to have a perfect vacuum, as some air will always remain in the vessel.

Why do you say that there will be about fifteen pounds pressure per square inch on the water ıe?

Because the pressure of the atmosphere on **EVERY OBJECT** at sea level is 14.7 pounds per

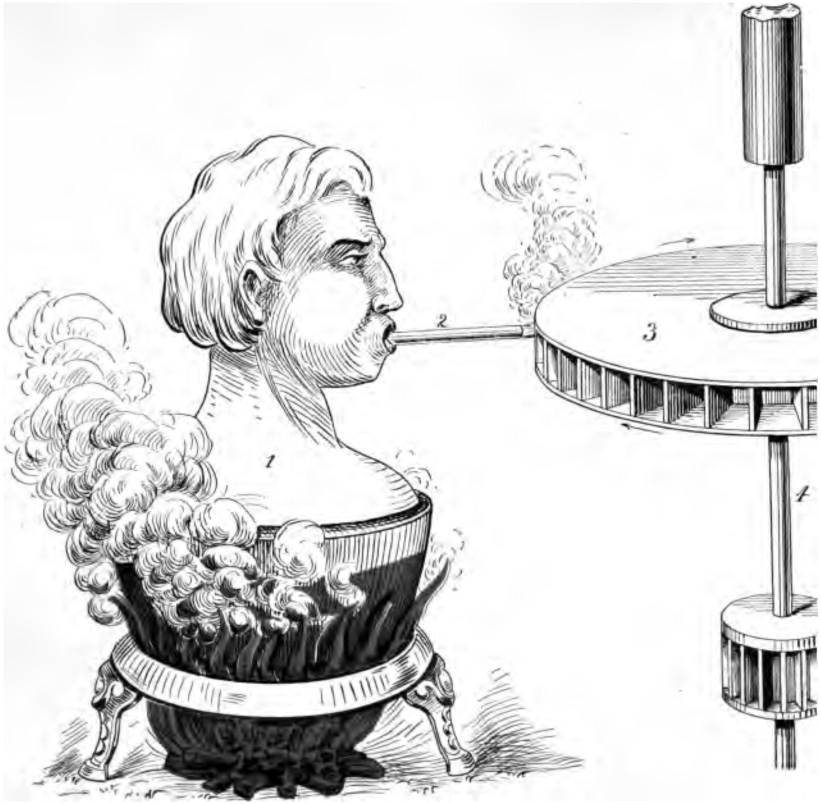

Illustration 2.

: inch, but for convenience we usually speak of this pressure as fifteen pounds per square inch, as :ing accurate enough for all ordinary purposes.

. What was the great **DEFECT** of the Savery engine?

. The **WASTE** of steam was enormous, the consumption of coal being about **TWENTY TIMES** at as is required by a modern steam engine to do the same amount of work.

. Who greatly **IMPROVED** upon the Savery engine, when and how?

. **THOMAS NEWCOMEN** in the year 1705 greatly improved upon the Savery engine by **'CING** the amount of steam necessary to be condensed in operating the Savery engine, by making a **PISTON** which worked in a **CYLINDER.**

. What do you mean by a **PISTON** and a **CYLINDER?**

. The piston is a **DISK** fitted to a rod, upon which disk the steam acts, forcing it back and n the cylinder, which is a hollow cylindrical shaped vessel closed either at **ONE** or **BOTH** ends.

. Describe the **NEWCOMEN ENGINE?**

. This engine is shown in **Ill. 4.** It consisted of a horizontal lever or beam pivoted at the center ırrying at one end a **HEAVY ROD** which was connected with the mine below. A piston was hung he other end of this lever, which piston worked up and down in a cylinder **OPEN** at the top. at atmospheric pressure (14.7 lbs.) was admitted from the boiler to the cylinder, and as the **SURE** was then the same on **BOTH** sides of the piston, the falling of the heavy pump rod **RAISED** ston. A jet of water was then introduced into the cylinder to condense the steam and form a **UM.** This left the piston with the pressure of the atmosphere (14.7 lbs.) on **ONE** side of it, and tle pressure on the other side, which difference in pressure forced the piston **DOWN,** and in this **AISED** the pump rod. Steam was then again admitted into the cylinder which allowed the pump

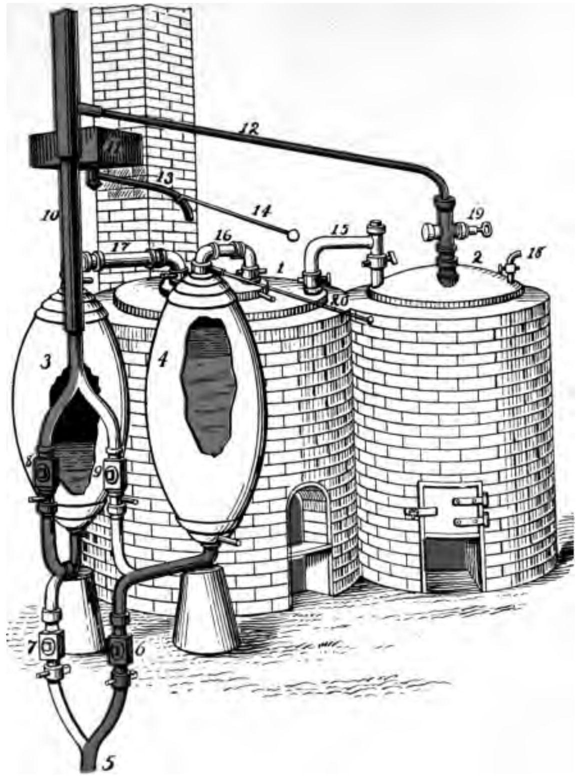

Illustration 3.

.l, and then again condensed, which raised the pump as before, and in this way the pump was ıted.

Q. What was the **CHIEF DEFECT** in the Newcomen engine?

A. The cylinders were usually made of **WOOD,** and the workmanship was so poor that a **TIGHT T** could not be made between the piston and the walls of the cylinder. This permitted the steam **SCAPE** from around the piston. To prevent this as much as possible, a jet of water was made to on the top of the piston, thus making a **WATER SEAL** through which the steam could not escape, ausing a great loss of heat.

Q. What was the greatest trouble with all the first engines constructed?

A. They required some one to open and close the cocks to admit the steam and then the water ndense it, and also the cocks to discharge same. Boys were usually employed for this work.

Q. How was the first **AUTOMATIC** engine constructed?

A. In order to get time to play, a boy by the name of Humphrey Potter rigged a catch at the of a cord which was attached to the overhead beam in such a way as to open and close these s, and in this way the first **AUTOMATIC** engine was constructed.

Q. Was the Newcomen engine more economical than the Savery engine?

A. Yes, but it was most wasteful of steam and very clumsy.

Q. What was the first improvement in the cylinders of this engine?

A. They were made of **IRON** instead of wood, but were cast rough, and the workmanship far perfect

Q Who greatly improved upon the Newcomen engine and introduced the first type of the **ERN STEAM ENGINE?**

A. James Watt in 1764.

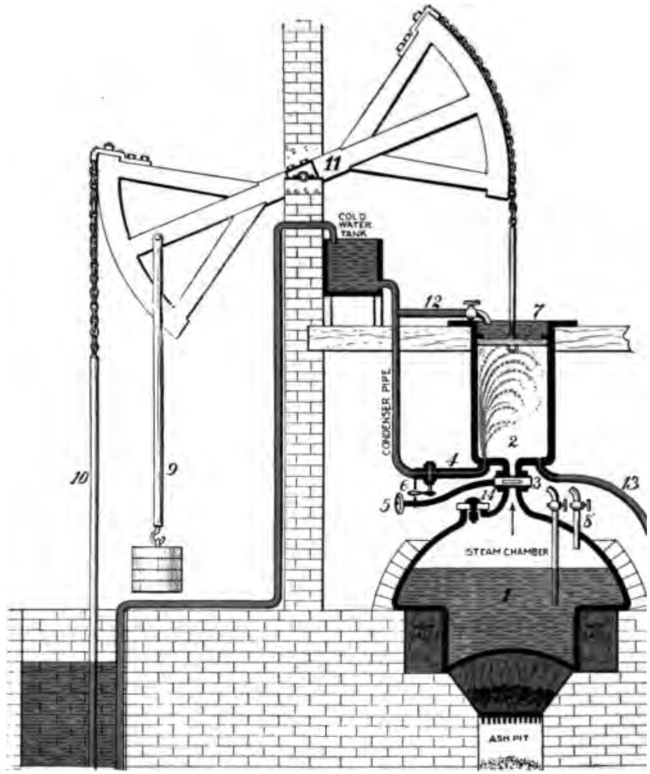

Illustration 4.

Who was James Watt?

He was an instrument maker in Glasgow, Scotland, and one of the greatest inventors who ed. He was the father of the modern steam boiler and steam engine.

What improvements did Watt make in the steam engine?

first introduced the use of the **SEPARATE** condenser and a **CLOSED** cylinder, together with a ıany changes which have been but little improved upon, even to the present day. The first en- ıstructed by Watt is shown in **Ill. 5.**

What was the advantage of having a **SEPARATE CONDENSER?**

Instead of condensing the steam in the cylinder itself, Watt used a **SEPARATE** vessel or **NSER** into which he injected the water to condense the steam and thus formed a vacuum. In y he kept the cylinder almost as hot as the entering steam, which is a great advantage, as we reafter see. He also made the piston **TIGHT** by using greater care in its construction, so that ıot necessary to keep it under a water seal, which seal greatly **COOLED** the piston and the r walls, thus causing a great loss of heat, thereby decreasing the efficiency of the engine.

What other improvement did Watt make?

He closed **BOTH** ends of the cylinder, thus not only preventing the air from cooling the piston, mitting the steam to act on **BOTH** sides of the piston, making the engine a **DOUBLE ACTING** All his predecessors had left one **END** of the cylinder open, which permitted the steam to be ly on **ONE** side of the piston.

What other improvement did Watt make?

He **JACKETED** the cylinder, which also aided in keeping the temperature of the cylinder the ; the steam which entered it.

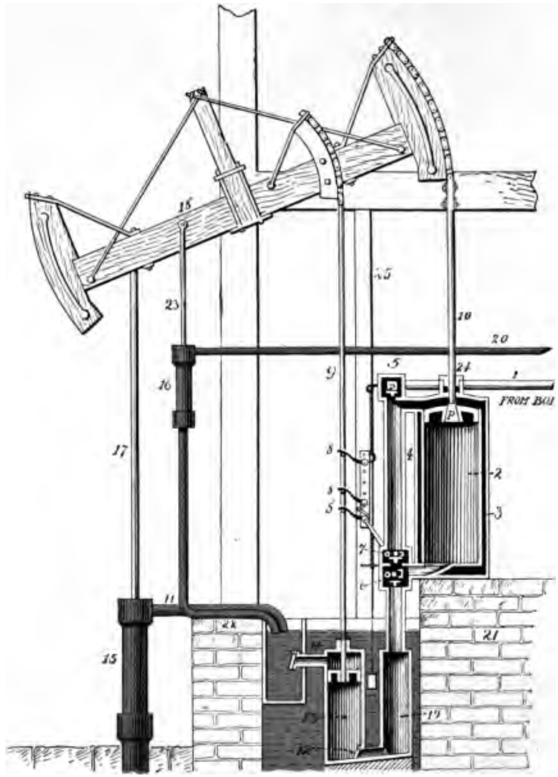

Illustration 5.

What other improvement did Watt make which was far more important than any of these?

He used the steam **EXPANSIVELY**, that is, the steam was shut off when the piston had made 'ART of the stroke, permitting the **EXPANSION** of the steam to complete the stroke, and ing greatly to the **ECONOMY** of the engine in the saving of steam, which would be otherwise

What was the next step in the development of the steam engine?

The invention of the "Compound" or **DOUBLE** cylinder engine by Jonathan Hornblower in his compound engine is shown in **Ill. 6.**

Describe this engine?

It consisted, as shown in the illustration, of **TWO** steam cylinders, one being the **HIGH** pres- ıder and the other the **LOW** pressure cylinder. The steam leaving the high pressure cylinder usted into the low pressure cylinder, and after doing its work in that cylinder was discharged condenser. The two piston rods were both connected to the same beam by chains, the same with all the other engines of that day. These rods passed through stuffing boxes in the heads, the same as in the Watt engine. As this engine had **TWO** cylinders the steam was l **TWICE** before its final discharge.

Was Hornblower's engine a success?

No, owing to the low pressure at which the steam was used, but the **PRINCIPLE** upon which ıis engine was correct, and added greatly to the **ECONOMY** of the steam engine.

Why is a compound engine more economical than a single cylinder engine?

It **REDUCES** the amount of steam used by reducing the cylinder condensation.

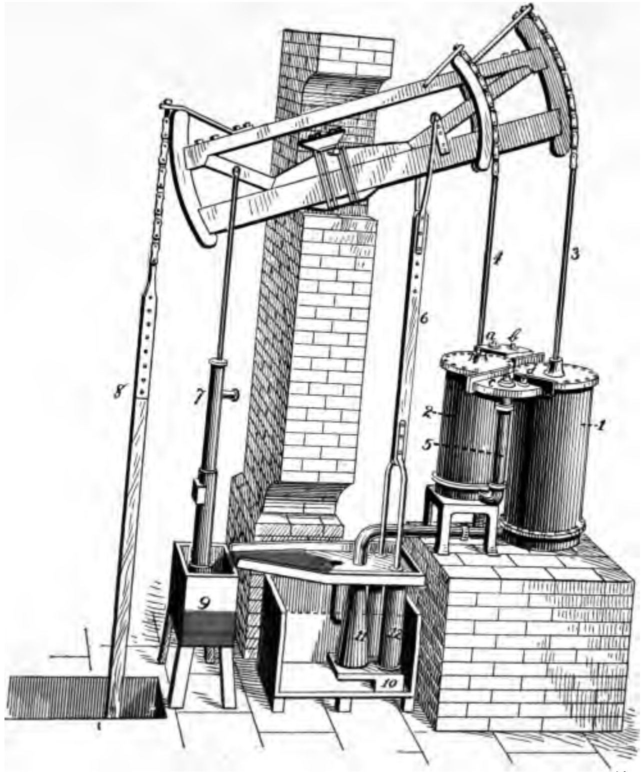

Illustration 6.

What was the next stage in the development of the steam engine?

The invention of the **CORLISS VALVE GEAR.** This form of valve gear was invented and first .ced by Geo. H. Corliss in the year 1848. It marked a new era in engine building. He first ·ed the governor-controlled cut-off, and the easy moving valves, with their liberal exhaust ports ;ake care of both the exhaust and the condensation. It was Mr. Corliss who also first designed per engine frame, and made the engine self-contained. His first engine is shown in **Ill. 7.**

Describe the construction of the Corliss Gear?

In the Corliss gear there is a separate admission valve and a separate exhaust valve for each the cylinder entirely independent of each other. The admission valves are operated by either one ɜ eccentrics, but they are automatically closed by dash pots or springs, when the piston reaches a .ted point of its stroke. This point will vary with the position of the governor, which position ry with the speed of the engine, which is controlled by the load on the engine.

ιe exhaust valves are opened and closed by the motion of a wrist plate to which these valves are 7 connected by rods or cranks. Both the admission and exhaust valves are cylindrical in shape, ; in cylindrical seats which extend across the ends of the cylinder. The wrist plate which oper- e exhaust valves alone, receives its oscillating motion from the eccentric which is fastened to .ft of the engine.

hen the piston reaches the point where the steam should be shut off, the trip gear is held in such ion by the governor that it releases the admission valve, which is snaped shut by the action of ;h pot, or spring. The exhaust valve is made to open by the independent action of the wrist rhich is operated by its eccentric.

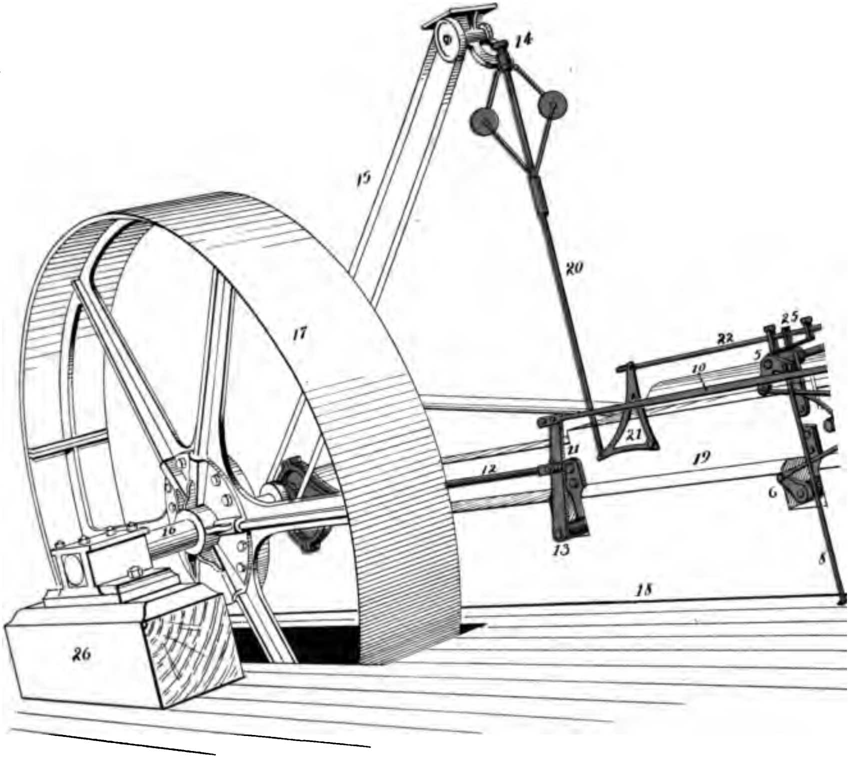

Illustration 7.

e advantage of the Corliss valve gear is the long range of the stroke through which the cut off varied, depending only on whether one or more eccentrics are used.

th one eccentric, the cut-off ranges from the beginning of the stroke to one-half, at which point entric starts on its return travel. With the use of two eccentrics this range can be extended al- e entire stroke, as the exhaust valves are then operated entirely independent.

What is meant by the **STROKE** of an engine?

The distance passed over by the piston in moving from one extreme position in the cylinder ther.

What did Watt find was necessary to obtain the **BEST** results, or **STEAM ENGINE EFFIC-** as it is called, from a steam engine?

He found, **"FIRST, THAT THE TEMPERATURE OF THE CYLINDER SHOULD ALWAYS BE ME AS THAT OF THE STEAM WHICH ENTERED IT; AND SECONDLY, THAT WHEN THE WAS CONDENSED IT SHOULD BE COOLED TO AS LOW A TEMPERATURE AS POSSIBLE."**

How are engines **CLASSIFIED?**

According to the WORK for which they are built.

Name the classes into which they are divided?

First: Stationary, Portable, etc., depending upon whether the engine is stationary, as in steam or, portable, as locomotives.

Second: Simple, Compound, Triple Expansion, etc., from the arrangement and number of **LINDERS.**

Third: Plain Slide Valve, Automatic Cut Off, Corliss, etc., according to the character of the **S** which control the distribution of the steam.

Fourth: Reciprocating and Rotary, according to the

Q. How are these classes subdivided?

A. First: Condensing engines; Second: Non-Condensing
Fourth: Double-Acting engines.

Q. How are engines classed that operate factories, office
character of stationary steam plants?

A. As **STATIONARY ENGINES.**

Q. How are marine and locomotive engines, hoisting engine
shovels, and all pumping, blowing and fire engines, classed?

A. As **PORTABLE** engines.

Q. What is a **SIMPLE** engine?

A. It is an engine in which the steam is used expansively in

Q. What is a **COMPOUND** engine?

A. It is an engine which has **TWO CYLINDERS**, the steam
final discharge.

Q. What is a **TRIPLE EXPANSION** engine?

A. It is an engine which has **THREE CYLINDERS**, that is, t
before its discharge.

Q. What is a **MULTIPLE EXPANSION** engine?

A. It is any engine in which the steam is expanded in **MOR**
hausted or discharged.

What is a **RECIPROCATING** steam engine?

In this type of engine the work is done by the **RECIPROCATING** motion of the piston, that is, n back and forth in the cylinder. This reciprocating motion must be changed into a continu- **ARY** motion before the power of the engine can be used.

What is a **ROTARY** engine?

In this type of engine the piston instead of **RETURNING** to its starting point, continues turn- ıe direction, the piston and crank being connected to the shaft and rotating in the same

What is a non-condensing engine?

It is an engine in which the steam after having been expanded in the cylinder is discharged into ›sphere, or into a heating system.

What is a condensing engine?

It is an engine in which the steam after having been expanded in the cylinder is discharged into ıser where it is brought in contact with some cooling substance by which it is **CONDENSED** ırtial vacuum produced behind the piston.

What is the object of so condensing the steam?

It is to remove as much as possible the **BACK PRESSURE** on the piston, and to thus increase n effective pressure on it throughout its stroke.

What are the reciprocating parts of an engine?

They are all the parts which move **BACK AND FORTH** either in a horizontal or vertical direc- ng viz.: (1) the piston, (2) the piston rod, (3) the cross-head, (4) the connecting rod.

Q. What is the **CYLINDER** of an engine?

A. It is that part of the engine in which the piston moves.

Q. What is meant by the term head-end and crank-end of the cylinder?

A. The head-end is the end farthest away from the crank shaft, while the crank-end nearest the crank shaft.

Q. What is meant by the **VALVE GEAR** of an engine?

A. The mechanism by which the steam is distributed.

Q. What composes the valve gear of an engine?

A. The distributing valves, the eccentric, the eccentric strap, the eccentric rod, the r the valve stem.

Q. What is the eccentric, and what is its purpose?

A. It is a disc or crank keyed to the shaft so that its center and the center of the s coincide. It is used to operate the distributing valve or valves.

Q. What is a single valve engine, and what is a four-valve engine?

A. A single valve engine is one in which a single valve controls the admission and dist steam for both ends of the cylinder, while a four-valve engine is one which has separate val admission of the steam to the cylinder, and for its discharge or exhaust.

Q. What is meant by the **CUT-OFF** of the valve?

A. It is the point of a piston's travel at which the steam admission port **CLOSES,** no fur being admitted to the cylinder during the remainder of the stroke.

Q. What is the object of cutting off the admission of the steam?

A. So as to allow for expansion of the steam, thus saving steam which means the savin

What is the purpose of **OUTSIDE LAP** on a valve?

In order to cut off the steam before the piston completes its stroke, and thus allow expansion.

What is the purpose of **INSIDE LAP** on a valve?

It is to close the exhaust port before the piston reaches the end of the return stroke, thus increas-ompression and forming a cushion of steam against which the piston strikes.

What is meant by **LEAD?**

It is the amount that the valve leads the crank, for it is the space the steam port is open when ie is on the center.

When is an engine on its **CENTER**?

When the piston is at the extreme point of its travel at either end of the cylinder.

How is the size of an engine indicated?

By the length of the **STROKE** and the **DIAMETER** of the cylinder.

Q. What is the difference between an **IMPULSE** and **REACTION?**

A. An impulse is the **MOMENTUM** given a body in a **FORWARD** direction by some otl striking it; while **REACTION** is a force acting in a **BACKWARD** direction relative to the impı

Q. Is the impulse and reaction always **EQUAL** and in **OPPOSITE** directions?

A. Yes.

Q. Can impulse and reaction be made to act in the **SAME** direction so as to **ASSIST** each

A. Yes, by using a **CURVED** surface, so that the impinging steam or water is turned **BA(** itself through an angle of 180 degrees. The impinged surface is then acted upon by **TWO** forc moving it in the **SAME** direction. The first is that due to the **IMPULSE** of the jet of steam c which acts until it reaches the **CENTRAL** point of the curved surface; and the **SECOND** for **REACTION** of the jet, which begins when the jet starts to flow **BACKWARD** from this central

Q. In what device was this principle first employed?

A. In the **PELTON WATER WHEEL.**

Q. Are the essential principles of **WATER** and **STEAM** turbines the **SAME?**

A. Yes, with two exceptions, viz.: (1) provision must be made in the steam turbine verting the **HEAT** energy of steam into **KINETIC** energy, that is, the energy of **MOTION,** anc steam turbine must be adapted to the much **HIGHER VELOCITIES** of steam.

Q. What is the chief requisite for the operation of any form of steam turbine?

A. The changing of the **MOTION** or direction of the flowing steam.

What is the fundamental principle in any economical steam motor, whether turbine or piston

The utilizing of the **EXPANSIVE** force of the steam.

Was the principle of expansion properly utilized in the Hero, Branca, or any of the **EARLIER** turbines?

No, in consequence of which the **WASTE** of steam was excessive.

When was this **EXPANSION** force first properly utilized in the steam turbine?

By Gustaf De Laval, the Swedish scientist, in the year 1883.

Had the expansive force of steam been utilized in the **RECIPROCATING ENGINE** previous to

Yes, by James Watt in the year 1782.

Since the year 1782 has there been any important thermodynamical improvement in the recip- engine?

Only **ONE,** the introduction of **COMPOUND** expansion.

From what does the **RECIPROCATING ENGINE** derive its **POWER?**

From the **STATIC** force of the steam expanding behind a piston.

From what does the **STEAM TURBINE** derive its **POWER?**

From the **KINETIC** energy of the expanding steam.

What does the **EXPANSION** of the steam produce in the reciprocating engine?

It produces a **FORCE** which presses on the piston.

What does the **EXPANSION** of the steam produce in the turbine?

It produces **VELOCITY** in a jet of steam.

Q. How **GREAT** is this velocity?

A. Often from 3,000 to 4,000 feet per second, that is, 35 to 45 miles per minute.

Q. Upon what does the velocity depend?

A. Upon the **DIFFERENCE** between the **INITIAL** and **DISCHARGE** steam pressures, the **SHAPE** of the orifice or nozzle through which the steam is discharged.

Q. What is the **MAXIMUM** flow of steam through a rounded orifice.

A. 1,500 feet per second, irrespective of the difference of the initial and discharge pressu is true whenever the **EXHAUST** pressure bears a ratio of 58 per cent to the initial pressure, **CRITICAL** pressure, which applies to all non-expanding nozzles.

Q. Why is this true?

A. Because the steam is free to expand in **ALL** directions, hence its energy is dissipated, no **VELOCITY.**

In consequence, the particles of steam issuing from the orifice **HOLD BACK** other part **DECREASING** the velocity of discharge.

Q. How can this trouble be overcome?

A. By the use of a **DIVERGING** nozzle. In such a nozzle the steam expands to the l sure **WITHIN THE NOZZLE ITSELF,** causing the steam to be discharged in the form of a s drical jet, equal in diameter to the **OUTLET** diameter of the nozzle. This permits the steam at the velocities the succeeding expansions will give it.

Q. Upon what then does the **VELOCITY** of the steam depend?

A. Upon the number of expansions given it, that is, the **ENERGY** and not upon the P in the boiler.

What is it that prevents **ALL** the steam in a boiler escaping **AT ONCE** upon any valve on the
)eing opened?

The **INERTIA** of the steam, that is, its inclination to remain in its present state or condition.

Does it take **ENERGY** to set steam to flowing through a pipe, a valve or any other orifice?

Yes, just the same as it does to get any mass in **MOTION** when it is at rest.

Can **GREATER EXPANSION** be obtained from the steam in the reciprocating engine, or the steam
?

In the **STEAM TURBINE.** With the best reciprocating engines the steam is not expanded more
) **TIMES,** while with the steam turbine 100 **EXPANSIONS** are not uncommon. To obtain as many
xpansions, the low-pressure cylinder of an engine must be made of enormous size, while to obtain
PANSIONS in the steam turbine, it is only necessary to make a slightly different **NOZZLE,** or add
three more rotars or wheels.

Into what **TWO** general classes may both water and steam turbines be grouped?

Into **IMPULSE** and **REACTION** turbines. This classification is not strictly correct, as all
al turbines are operated **BOTH** by the action and reaction of the working fluid.

Do the **MODERN** types of steam turbines differ essentially from the Hero and Branca turbines?

No, they are but the **PROTOTYPES** of these first two turbines.

What were the principal **DEFECTS** in the Hero and Branca turbines?

No proper provision was made for the expansion of the steam, also improper construction of the
therefore, but little of the **HEAT ENERGY** of the steam was converted into **KINETIC** energy.

What are the two chief requisites for a **SUCCESSFUL** steam turbine?

As much of the **HEAT** energy as possible must be converted in **KINETIC** energy, and this kinetic

Illustration 8.

then utilized in an efficient manner. Second, the turbine must be capable of perfect **SPEED** **,ATION** without a too great loss of efficiency.

Who first embodied these requirements in a practical steam turbine?

Gustaf De Laval in the year 1883, and C. A. Parsons in the year 1884.

What are the fundamental principles of the DeLaval steam turbine?

This turbine is purely an **IMPULSE** turbine, consisting of a single turbine wheel, carrying **ONE** buckets, to which the steam is delivered in free jets at the highest possible velocity. e steam is discharged from stationary nozzles, so **TAPERED** as to increase their cross-sectional ward the outlet end of the nozzle, and so constructed that the steam is fully expanded down ɔressure in the exhaust chamber of the turbine **BEFORE** it leaves the nozzle. In consequence of remely high velocity so given the steam, its **WHOLE** available energy is fully transferred into **IC** energy.

What are the fundamental principles of the Parsons steam turbine?

This turbine is called a **REACTION** turbine, but, in fact, is a **COMBINATION** of the impulse and ı principles; no **NOZZLE** is employed, but there are **ALTERNATE** rows of **STATIONARY** guide The steam flows between a **FIXED** row of directing blades, which serve the purpose of steam , and a **REVOLVING** row of similar blades, the **REVOLVING** rows of blades acting both in the capac- ɔuckets and nozzles, the same as in a reaction turbine. Instead of the steam being expanded **N** divergent nozzles, as in the De Laval turbine, the steam progressively **INCREASES** from the the exhaust in the annular space between the rotating spindle and the cylinder of the walls of ɔine. The entire expansion, which is almost entirely **ADIABATIC**, i. e., no heat is taken in or given the steam cycle, is carried out within this annular compartment, which is exactly similar to a divergent steam nozzle, such as is employed in the De Laval turbine, as shown in **Ill. 8.**

The Electric Gene

THE ELECTRIC GENERATOR

S **CHRISTIAN OERSTED,** a professor in the University of Copenhagen, in the year 1819, dis-he production of magnetism by electricity, and explained the relation between magnetism and r.

l. I, is shown the simple apparatus used by him in making his great discovery. He used an magnetic needle or compass, such as shown in the illustration, over which he held horizontally a ire in the same direction as the needle when at rest. So long as **NO CURRENT** is flowing through the needle will remain stationary, but as soon as an electric current is made to pass through the needle will be at once deflected. If the current be made to pass in the direction as indicated by arrow in the illustration, then the needle will be deflected in the direction indicated by the small rrows. If, while still holding the wire in the same position above the needle, the current is made hrough it from north to south, it will cause the north pole of the needle to be turned towards If, however, the current is made to pass through the wire in the **OPPOSITE** direction, that is, south to the north, then the north end or pole of the needle will be deflected to the west. Should be placed **BELOW** the magnetic needle instead of above it as shown in the illustration, then ıetic needle will be deflected in opposite directions as when the wire was placed above the needle.

ong as **NO CURRENT** flows through the wire, no magnetism is produced, and hence the mag-edle will remain stationary. There must be a **MOVEMENT** of the electric current to produce sm in a conductor, hence a wire or any conductor on an **OPEN CIRCUIT** possesses no magnetic i.

s experiment of Oersted clearly demonstrated that when an electric current was flowing through

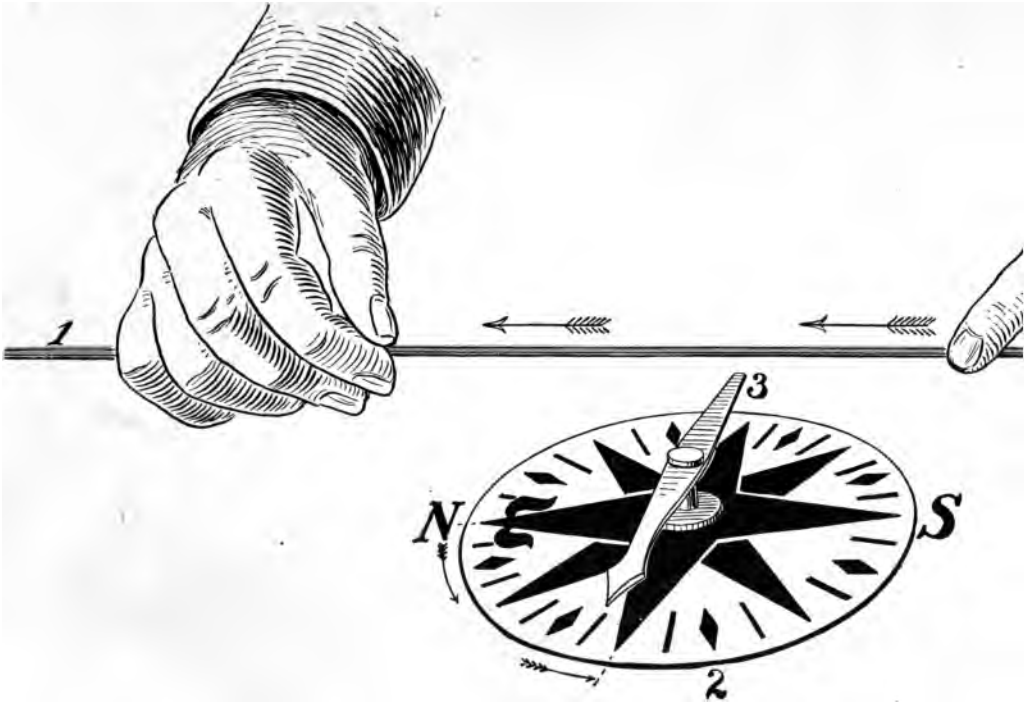

Illustration 1.

ıctor that it produced a magnetic field or whirl around the conductor, and that the conductor ɔd all the properties of a magnet so long as the current continued to flow.

Who first succeeded in so inducing an electric current?

MICHAEL FARADAY, who was born in 1791 and died in 1867.

In what year did Faraday try first to convert magnetism into electricity?

He began his experiments in the year 1822, but did not succeed until August, 1831, when, in a f experiments extending over ten days, he was not only successful, but also fully demonstrated ɔther most important properties of the magnetic lines of magnets.

What was Faraday's **FIRST** attempt in these ten days to obtain electricity by induction?

He coiled two wires around a wooden rod, the wires not touching each other but lying closely r. He then sent a current through one of the wires. Upon joining up a galvanometer to the ·ire he looked to see if any current was **INDUCED** in it by the current flowing along the **FIRST** ıt found none.

Was this experiment of any value to him?

Yes; for he noticed a faint disturbance in the galvanometer when the battery connection was r broken.

What did this show?

That to produce electricity there must be a **CHANGE** in the magnetic state or in the **INTENSITY** :urrent, for the current produced no inductive action on the other wire so long as it flowed with **RM** intensity, but only at the instant when contact was made or broken was any disturbance of ʋanometer noticeable.

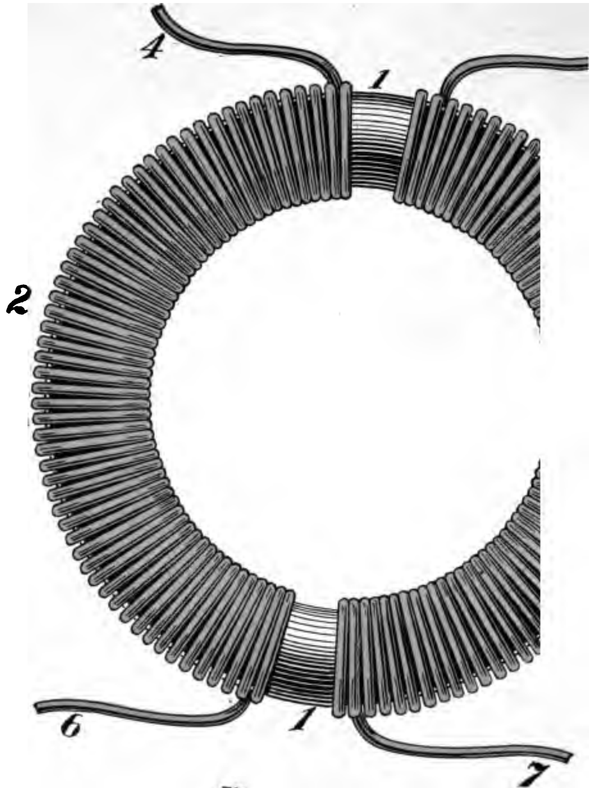

Illustration 2.

What was the **NEXT** step taken by Faraday?

He had a **RING** made of soft iron, $\frac{7}{8}$ inch thick and 6 inches in external diameter. On this wound **TWO** coils of insulated wire as in **Ill. 2.** There were 72 feet of wire in one coil and 60 feet in er coil, the two coils being separated from each other by a short space. He connected a battery of ıll cells to one of the coils, while the other coil was connected to a simple galvanometer made of a vire passed over and under a compass needle. On making the circuit between the first coils and the , there was an immediate and transient effect on the galvanometer connected in the second coil. ile was deflected, oscillated, and finally settled down in its original position. On **BREAKING** nection with the battery the galvanometer needle was again deflected but in an **OPPOSITE** direc- that when the circuit was made. In **Ill. 3** is shown this ring with its connections. From at value of the discoveries which he made with this ring, it is called **FARADAY'S RING.**

What was shown by this experiment?

As the two coils were electrically separated from each other, there being no connection of the the coils, it was clear that the current in the first ring flowing from the battery had **INDUCED** **ENT** in the second coil, and that the iron ring assisted in this result.

How did the ring assist in inducing the current in the second coil?

The circulation of the current in the first coil had magnetized the ring, and when the current ned off the ring ceased to be a magnet. The action of the magnetism of this ring, or **IRON** core, uced a momentary electric current in the second coil, when the current was turned on, and again ntary current when the current was turned off from the battery.

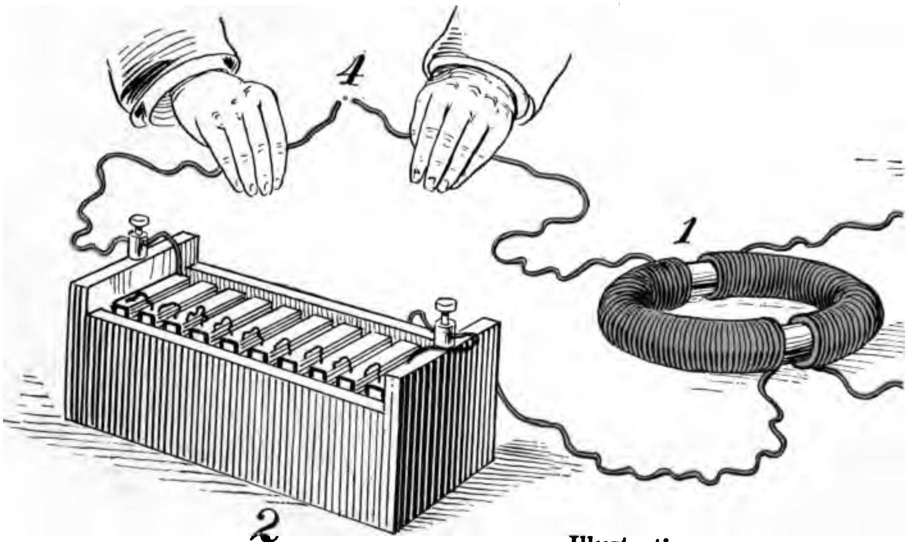

Illustration 3.

ıy was the current induced in the second coil only on making or breaking the connection of l with the battery?

ər the same reason as shown by his first experiment, viz.: magnetism at **REST** has no induc-, and the magnetism of the ring was at rest except at the instant of making and breaking the cuit.

Vhat was the **THIRD** experiment made by Faraday?

ls it was evident that it was the **MAGNETISM** of the electro-magnet, made by passing the round the iron ring, which induced the current in the second coil, on the next day Faraday this apparatus so as to use the magnetism of two common magnets of steel instead of the coil, ith the ring had formed, as we have seen, an electro-magnet. He, therefore, connected the gal-er to a new coil not wound on a ring as before, but around a short cylinder of soft iron, as shown Upon bringing the poles of the two bar-magnets of steel in contact with the ends of this bar or on removing them, the galvanometer showed the presence of an induced current in the coil.

What did this experiment show?

That electricity could be produced from magnetism in **MOTION.**

What did it show in reference to the current?

That the current must be in **MOTION** in order to have any **INDUCTIVE** effect, for it has been t only when the **STRENGTH** of the current was changing (increasing upon completing the cir-l decreasing or dying away upon breaking the current) was any current induced in the coil.

had been the **MISSING FACTOR** in all previous attempts to induce an electric current?

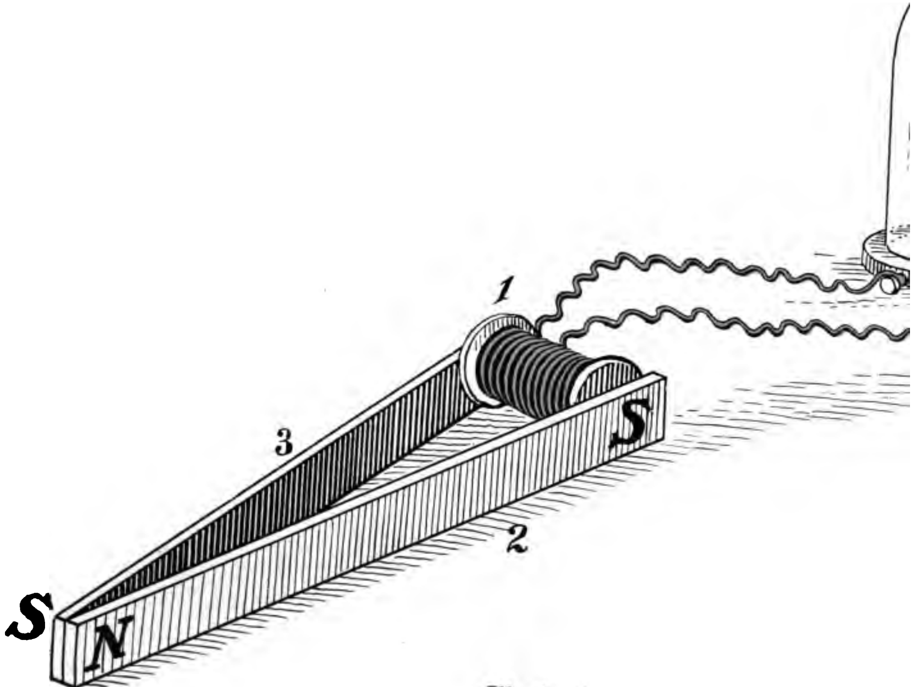

Illustration 4.

How did Faraday next demonstrate that **MOTION** was necessary to induce a current?

On the fifth day he used a hollow cylindrical coil made by coiling 220 feet of wire around a ›ard tube. Upon joining this coil with a galvanometer, as shown in **Ill. 5,** and plunging a cylin-ar-magnet of steel 8½ inches long and ¾ inch thick into the tube around which the wire was coiled, vanometer showed a momentary current, and upon quickly pulling out the bar-magnet the gal-:ter **AGAIN** showed the presence of a current; but the needle moved in an **OPPOSITE** direction hat it did when the magnet was inserted in the tube.

What did this show?

That the mere **PRESENCE** of a magnet near the coil was sufficient to induce a current, and that **CT** of the magnet with the coil was not necessary.

How did this prove **CONCLUSIVELY** that **MOTION** was necessary to induce the current?

As the magnet lost none of its magnetism during the operation, and as a **CURRENT** was only l at the instant when the magnet was plunged into the coil or pulled out, it was the **ENERGY** ed in working the magnet in and out of the coil that induced the current. This was the first **ANICAL GENERATION** of a current by the expenditure of energy.

What did Faraday call this phenomenon?

MAGNETO-ELECTRIC-INDUCTION.

What did Faraday next do?

On the ninth day he was able to construct an electrical machine. To do this he used a powerful oe magnet, and into the polar gap, where the magnetic field was strongest, he introduced a wheel, of copper, 12 inches in diameter and ⅕ inch thick, fixed on a brass axis, which was mounted in so that the disc could be revolved by hand. Against the **EDGE** of the disc he pressed a collector

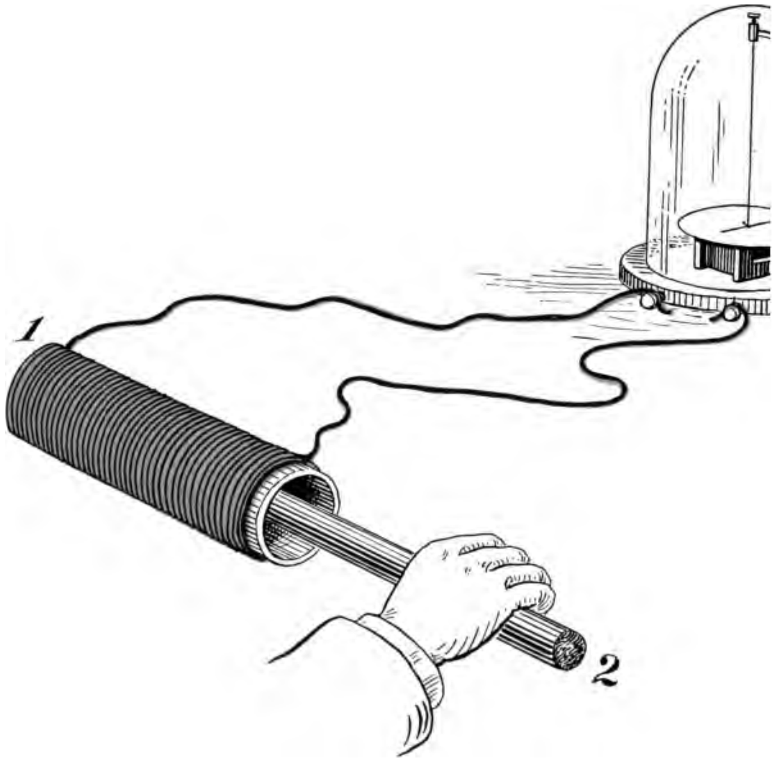

Illustration 5.

ıgy metal, and a second similar collector against the **AXIS,** to which collectors he attached a ›meter by means of wires, as shown in **Ill. 6.** On revolving the disc a current was continuously ed, which current produced in the galvanometer a steady deflection. When the direction of the ı of the disc was reversed, the direction of the current was reversed, this being shown by the ɔf the galvanometer being deflected in an opposite direction to that which it was at first deflected. ıs the **FIRST** dynamo ever constructed.

What did this show?

That a **PERMANENT** current of electricity can be generated by ordinary magnets.

What further great work did Faraday accomplish?

He demonstrated that in order to create any of these inductive effects the copper conductors › move as to cut **ACROSS** the magnets, or the magnetic lines must so move as to cut across the conductors.

To what two men is the world largely indebted for its material advancement?

To James Watt, the father of the steam engine; and Michael Faraday, the father of practical ity.

THE DYNAMO

What is a **DYNAMO-ELECTRIC** machine?

It is a machine to produce an electric current.

What do you mean by **DYNAMIC?**

It is derived from the Greek word, **DYNAMIS,** which means **POWER;** and is used to denote **NICAL** energy.

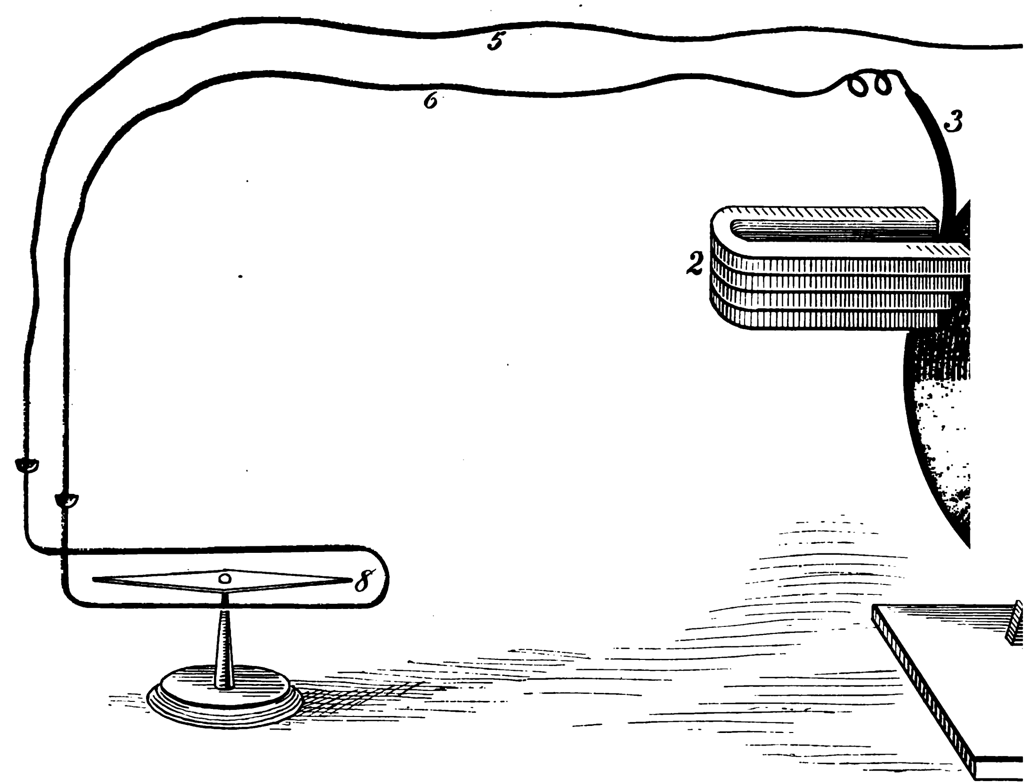

Illustration 6.

What, then, is a **DYNAMO?**

It is a machine to produce an electric current by mechanical energy, such as is given by a steam or turbine.

In what sense is the term dynamo now chiefly used?

To designate **CONTINUOUS** current machines, while those which generate an alternating cur-e designated as **ALTERNATORS.** The term dynamo is also employed largely to describe elec-ıachines used solely for **LIGHTING** purposes, to distinguish them from electrical machines used **VER** purposes. The machines last mentioned are called **GENERATORS.**

What most novel principle applies to all machines for the generation of electrical currents?

Their **REVERSIBILITY,** for when driven by mechanical power they generate **ELECTRIC** s but when supplied with an electric current they generate **MECHANICAL** power.

Can the **SAME** machine without any change whatever be used for this twofold purpose?

Yes, differing in **NAME** only.

What names are given to those machines which convert mechanical energy into electrical and to those which convert electrical into mechanical energy?

Electrical generators are called dynamos, alternators, or generators, differing only in the char-f the current produced; while those machines which convert electrical energy into mechanical are called **MOTORS.**

Do any of these machines really **GENERATE** electricity?

No; they merely produce sufficient **PRESSURE** to cause the electricity to flow from one point her.

Q. How do we know that no electricity is generated by them?

A. If we measure the current flowing out along one wire and returning by the other will be found practically the same. Only so much air or water can flow out of a pump a flows into it at the other end.

Q. Do the same laws which control the flow of water apply to the electrical current?

A. Yes, exactly the same. Water will not flow through a pipe unless there is suffic on the water to force it through, and to generate this pressure a pump is usually employed. does not create or generate the water any more than a dynamo creates or generates electr neither case can a current exist without sufficient pressure to produce the flow or current.

MECHANICAL GENERATION OF CURRENTS

Q. Of what does every electrical generator consist?

A. Of **TWO** parts, one of which remains **STATIONARY,** while the other is made tc One of these parts is called the **ARMATURE,** and the other the **FIELD MAGNET.**

Q. Which part is the **FIELD MAGNET,** and which the **ARMATURE?**

A. That part which, whether stationary or revolving, maintains its magnetism **STEA** the revolution is called the **FIELD MAGNET.** It consists of one or more magnets, usually nets, firmly fixed in an iron frame, the purpose of these magnets being to create the magı flüx, to be cut across by the conductors as they revolve in the magnetic field. This part i **STATIONARY** part of generators, though in modern types of alternators it is often made to

What is the **ARMATURE?**

The **ARMATURE** is that part which, whether revolving or fixed, has its magnetism **CHANGED** ıe machine is in motion. Usually it is the **REVOLVING** part, and consists essentially of a number er conductors joined together and grouped in a particular way for the circulation of the induced s. The revolving copper conductors as they **ROTATE** cut the invisible magnetic lines emanating e field magnets and thereby induce electro-motive forces, as was first demonstrated by **FARADAY.**

What then is the **PURPOSE** of an electric generator?

To induce electro-motive forces, or pressure, to **FORCE** the electric current around its circuit. . 7 is shown the simplest form of an electric generator.

Is the generator itself a part of the circuit?

Yes; the current is forced out from the machine along the circuit from one terminal, and flows to the machine at the other terminal.

How are the two terminals designated?

The current flows **OUT** from the machine over the **POSITIVE** terminal and wire, and flows back, **URNS,** to the machine over the **NEGATIVE** wire and terminal.

What other essential part has an electrical generator?

The device for **COLLECTING** the currents from the revolving armature and sending it out on ɜs, or mains, of the circuit.

How is this done?

As the armature is revolving all the time a current is being generated, it is evident that the must be a **SLIDING** contact, which must press against the revolving armature. Such **SLIDING** s are called **BRUSHES,** which are connected to the mains and at the same time press against the

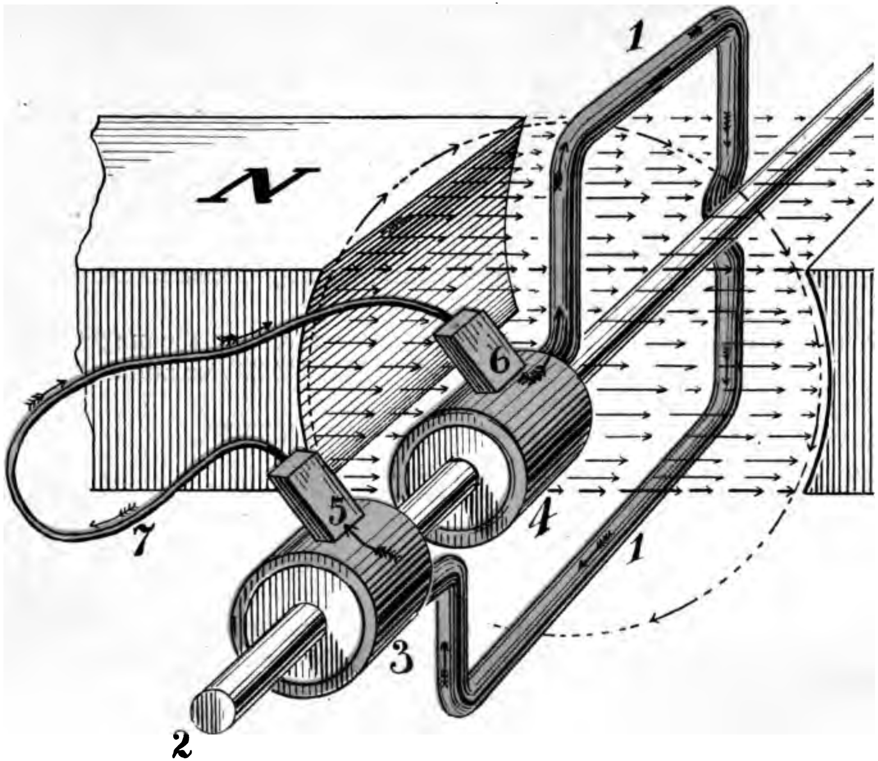

Illustration 7.

e. These brushes are provided with special brush holders, which are mounted upon an adjust-
ne or rocker.

Do these brushes press **DIRECTLY** against the armature?

No; they press against either a **COMMUTATOR** or a **COLLECTOR.** These are attached to ature and revolve with it.

Has a dynamo always more than **ONE** coil?

Yes, in practice the number of coils on a direct current machine ranges from sixteen to several l, according to the type and size of the dynamo.

Can the same electrical pressure, or E. M. F., be generated by revolving the magnets around ature so as to cause the magnetic flux to be cut by a **STATIONARY WIRE** or armature?

Yes, it is only necessary to cut the lines of force at right angles.

. **8** is shown a generator taken apart to show the **FIELDS** and **ARMATRUE.**

Upon what does the E. M. F. of an electrical generator depend?

Upon the **SPEED** of the machine, and the **SIZE** of the magnets.

Why is it necessary to put so many wires on the armature?

In order to obtain the required E. M. F. at a safe speed and with a moderate size machine.

How does the **SPEED** effect the E. M. F.?

The E. M. F. furnished by each wire or armature conductor is proportioned to the **NUMBER** netic lines **CUT** per second by that wire or conductor, consequently the higher the **SPEED** of the e the more lines of force will be cut per second.

How does the size of the **MAGNET** effect the E. M. F. of the machine?

The size of the magnets determine the **NUMBER** of magnetic lines in the field, and for each

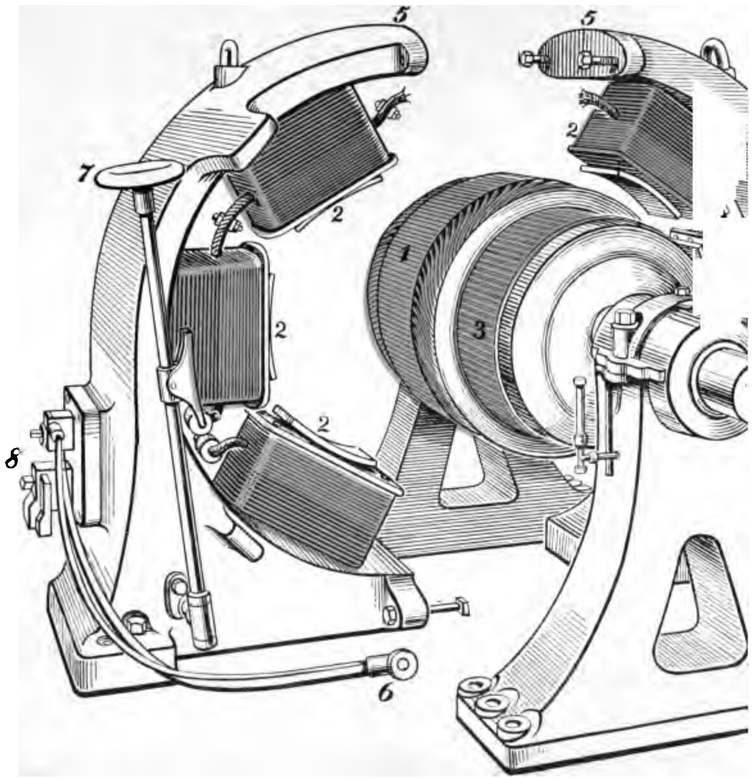

Illustration 8.

o,ooo of such magnetic lines cut per second, **ONE VOLT** of E. M. F. is generated in the wire or or, consequently the **LARGER** the magnets the **GREATER** the E. M. F. generated.

Does the speed of the machine or size of the magnets also determine the amount of the current ; by the dynamo?

No, the **SIZE** of the wire used on the commutator and the manner of **CONNECTING** the wind- ne determine this, the **LARGER** the wire, the more current it will carry without heating.

Where is the current in a dynamo produced?

In the **ARMATURE** coils.

Where do the field magnets get the current to excite their coils?

From the armature.

How is this done when the dynamo is at **REST** and no current is produced?

All iron masses **RETAIN** a small amount of magnetism after having been once magnetized, '**RESIDUAL**" magnetism. This residual magnetism induces a small amount of E. M. F. in the re and a small amount of current will therefore pass through the field coils, which in turn increases gnetism of the field, that is, the number of lines of force cut by the armature, and this in turn ɜs the flow of the current in the armature and which continues to increase the "excitation" of d until finally the machine is built up to its normal capacity.

Does **ALL** the current sent out from the armature pass through the field coils?

That depends on the field windings.

Why is a difference in the field windings made?

To adapt the machine to the different requirements of the **WORK** to be done.

Q. How do the requirements of the **WORK** differ?

A. In **ARC** lighting, the **CURRENT** must be kept constant, while
and **POWER** circuits, the **POTENTIAL** or E. M. F. must be kept consta

Q. In order to keep the **CURRENT** constant, what must be done

A. The whole current must be passed through the fields, and as t
be made to **AUTOMATICALLY** vary so as to keep the current constar

Q. In order to keep the **E. M. F.** constant, what must be done?

A. Only a small part of the current must be "shunted" through tl
regulated according to the load, a rheostat being used for this purpose

Q. Is this shunted current **AUTOMATICALLY** regulated?

A. No, the rheostat is operated by an attendant. As the load inc
that the field windings take **MORE** current, and as the load decreases th
LESS current.

Q. How does the operator know when the load increases or decr

A. By the use of a pilot lamp or the voltmeter which indicates tl

Q. Is there any way there can be an **AUTOMATIC** preservation o

A. Yes, by what is known as a **COMPOUND** winding of the field

Q. How is this done?

A. By means of **TWO** windings in the field instead of only **ONI**
series and shunt windings. With these two windings, the lamps are
the load, and not too dim at the high point of the load.

How do these two windings differ?

The series winding consists of a few turns of **HEAYV** wire, while the **SHUNT** winding consists : number of turns of **FINE** wire.

What is the **EFFECT** of these two windings?

The **HEAVY** wire, or series winding, takes **ALL** the current that the dynamo produces, hence current the dynamo produces, the **STRONGER** it makes the fields. The fine wire, or shunt takes only what the dynamo produces when there is little or no current coming from the arma- onsequently, when there is a heavy current necessary to take care of a heavy load, these two act in **UNISON,** the effect of the **TOTAL** current passing through to the series winding being ed by the small amount of current passing through the shunt winding, which is regulated by a

We therefore see that the series winding adds as much additional magnetism to the fields as ed to compensate for the **LOSS** caused from armature reaction and drop in the line. The series is therefore called the **"COMPENSATING"** winding. In this way the E. M. F. is **AUTOMATIC-** ept constant, though the current varies. A much closer regulation can also be obtained than e winding alone is used.

Have **BOTH** alternating and direct current machines these different field windings?

No, only **DIRECT CURRENT** machines.

Why have not alternating machines also these different field windings?

Because the fields of an alternating current machine must be excited by a **DIRECT** current, re would be no gain in so regulating the current or E. M. F. of such machines.

ernating current machines are known as **SEPARATELY** excited machines, while direct excited es are known as **SELF** exciting machines.

. **9** is shown a complete modern electric generator.

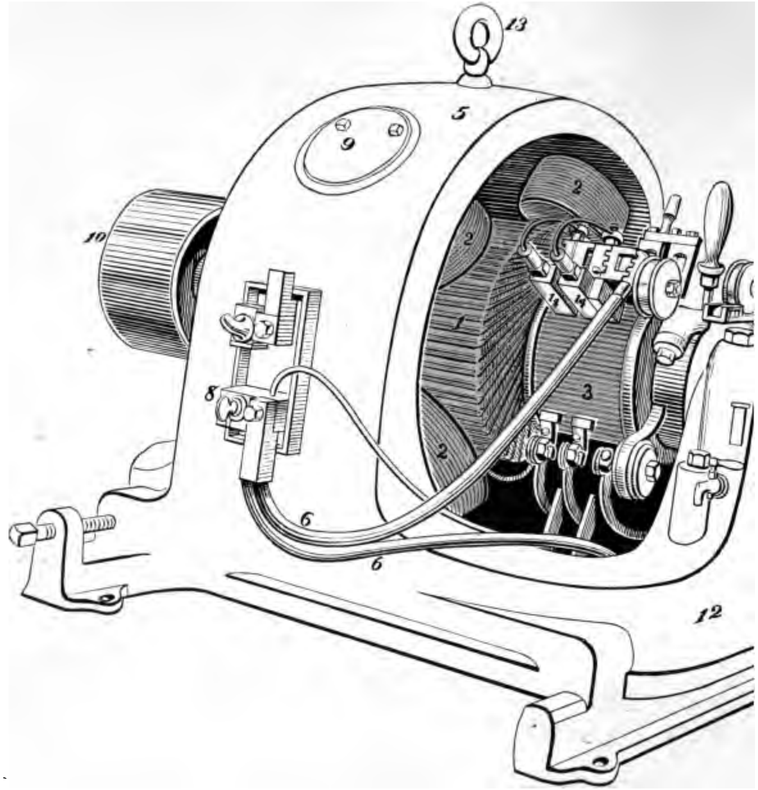

Illustration 9.

Since the current when produced is **ALTERNATING,** how is it changed into a **DIRECT** current?
By the use of a **COMMUTATOR,** which device takes the place of collector rings on **ALTERNA-**
s alternating current machines are called.
How is a commutator constructed?
Instead of being a **SOLID** metal ring, as is a collector, it is made up of segments, each segment
ulated from the other. In this way the current is made to flow always in the same direction
ut the external circuit.
How does the commutator do this?
When the E. M. F. is at zero, both brushes rest against both segments, but when the E. M. F.
or decreases, the positive brush rests against one segment and the negative brush against the
When the E. M. F. again becomes zero, it again rests against both brushes. As the E. M. F.
reases, but in an **OPPOSITE** direction, the location of the two segments change, the positive
ways receiving the outgoing current and the minus brush the incoming current. In this way
nt is always sent out in only **ONE** direction.
Into what three classes are all direct current machines divided?
Into (1) series wound; (2) shunt wound; (3) compound wound machines, depending upon
ing of the field magnets, and how these windings are **CONNECTED** to the **ARMATURE.**
How is the field winding connected on a **SERIES** machine?
To one brush, and to the external circuit.
How are the field windings connected on a **SHUNT** machine?
Between the brushes.

Q. How are the two field windings connected on a **COMPOUND** machir

A. One winding is connected in **SERIES,** and the other winding in **PA**
and external circuit.

Q. What do you mean by being connected in **SERIES?**

A. The positive and negative terminals being connected together, the s
DEM, that is, one in front of the other.

Q. What do you mean by in **PARALLEL** or **MULTIPLE?**

A. All the positive terminals being connected together and the negat
same as two horses **ABREAST,** that is, side by side.

Q. What is meant by **SHORT SHUNT** and a **"LONG SHUNT"** on a com

A. A **SHORT** shunt is when the shunt coils are connected in shunt l
LONG SHUNT when the shunt includes **BOTH** the armature circuit, that is
brush, and also the **SERIES** coils.

Q. What is the **EFFECT** of connecting cells or dynamos in **SERIES?**

A. It increases the **ELECTRICAL** pressure or E. M. F. or voltage, the c

Q. What is the effect of connecting them in **PARALLEL** or **MULTIPLE**

A. It increases the **CURRENT** or amperage, the E. M. F. remaining the

Q. What is an **EQUALIZER?**

A. It is a connection made between electrical machines for **EQUALIZ**
over a system.

). How is the equalizer **CONNECTED** between two or more compound wound dynamos operated rallel?

A. Into the **SERIES** coil and **POSITIVE** brush terminal on one machine, over to the **SERIES** coil **POSITIVE** brush terminal on the other machine·

). How is it connected to the switch board?

A. To the **MIDDLE** blade of a three-blade switch.

). What are **BUS-BARS?**

A. They are insulated copper bars to which the different terminals of electrical machines are con- ed for convenience, instead of connecting the terminals of one machine to the terminals of the other. ie positive terminals are connected to the positive bus-bars, all the negative terminals being connected e negative bus-bars. When an equalizer is used, it is connected to a **THIRD** bus-bar, usually placed een these two bars.

Q. Will compound machines run satisfactorily together in parallel if their series coils are **NOT** ected together by an equalizer?

A. No, for should the pressure at the terminals of one machine fall below that of the other it would ediately take a smaller proportion of the load and consequently the current in the field coils would t once reduced. This process would go on until finally the machine would cease to supply current, the current from the other machine flowing in the field coils in a reverse direction, would **MOTOR** machine, driving it in an opposite direction to which it previously ran as a dynamo.

By using an **EQUALIZER,** the whole of the current generated by the plant is divided among the s coils of the machines equally, thus maintaining them constant and obviating all danger of reversal **OLARITY.**

Q. With what other machines is an equalizer connection used?

A. In coupling **SERIES** dynamos in parallel.

Q. How is a new machine switched into parallel with one **RUNNING?**

A. The voltage at the new machine must be **BUILT** up to be equal, or one running before closing the switch.

Q. How is a dynamo **CUT OUT** of a circuit?

A. It is first necessary to **REDUCE** the load to a few amperes, either by or by cutting resistance into the shunt circuit by means of the rheostat or hε then, must the switch be **OPENED.**

Q. Is there any difference between the armature winding of an alternaı machine?

A. No, but the **GROUPING** of the windings is different.

Q. Does the E. M. F. rise and fall **TWICE** in each revolution of the armatı

A. Yes, in a bi-polar machine, it rises and falls every time a coil passes ε pair of poles.

Q. What is a **CYCLE?**

A. A cycle represents the current's strength, or E. M. F., during each **CO]** single coil in a bipolar field, i. e., a field having **TWO** poles.

Q. What is an **ALTERNATION?**

A. An alternation represents the change in a current during **ONE-HALF** (coil, and hence **ONE** cycle is composed of **TWO** alternations.

). What is **FREQUENCY?**
\. The **NUMBER** of cycles occurring **PER SECOND** is designated as the frequency.
). How is the frequency obtained?
\. Multiply the number of **REVOLUTIONS** per second by the number of **PAIRS** of poles.
). How are alternators **CLASSIFIED?**
A. With respect to the character of the current they develop, viz., single phase, two-phase, three-
e, polyphase or multiphase machines.
Q. Upon what does the character of the current developed depend?
A. Entirely upon the **ARMATURE** winding.
Q. What is the difference between the armature winding of a single, two and three phase machine?
A. With a **SINGLE** phase machine only about **ONE-HALF** of the surface of the armature is wound.
ıld an additional winding be placed on the armature in the space left vacant, then **TWO** separate and
nct currents can be supplied over the same circuit at the same time, and the machine then becomes
VO-PHASE alternator.